SEED CRUSHING COMPOUND and PROVENDER MILLING

VOLUME II.

By
H. MOORE
and
A. S. MOORE, A.M.I.Mech.E.

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FOREWORD

It is explained in Volume I of this work that whilst classes were formed for the Seed Crushing, Compound and Provender Milling Industries, there were no text-books on these subjects to which students and others could refer for information.

"Milling," the principal organ in this country and Europe of the flour milling industry, undertook to remedy the text-book deficiency in the case of the seed crushing, compound and provender milling industries. The first volume appeared in the early autumn of 1947 and the present volume is Part II of the work.

In each case the volume consists of lessons given at the Liverpool classes by Messrs. A. S. and H. Moore, and it is these lessons, carefully revised and amplified, that constitute the contents of the respective volumes.

The Publishers desire again to tender their thanks to the authors for their help and co-operation and also to the Assistant-Editor of "Milling" (Mr. G. Strain) for the extra personal trouble he has taken in the production of the volumes.

1948. L. F. SHEPPICK.

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PART I

SEED CRUSHING

by

H. MOORE

CHAPTER I.

CAKE MOULDS—Manual Operation

The function of the cake mould is the production of a uniform mass of prepared meal which can be carried easily and inserted between the plates of the Anglo-American hydraulic press, at the same time increasing the density of the meal and thereby increasing the crushing capacity of the press. Moulds may be manually or automatically operated, but in both cases the function is the same. It is important that the moulding operation be performed quickly to avoid heat losses while the press is open. It is important also that its movements be easy and simple in order to avoid fatigue to the operator.

The manual type of mould will produce a satisfactory type of cake, but much of the operation calls for a considerable physical effort on the part of the moulder. With the automatic mould, however, most of the physical effort associated with the manual mould is obviated. Since both the manual and automatic types are in use at the present day, however, each will be described.

Manual Mould

The chief parts of the manual type of the mould consist of a cylindrical base casting carrying the mould ram, the latter being surmounted and secured to a strong, steel table. Pivoting from a point at the rear of the cylinder casting is a steel frame, counter-balanced for easy manipulation, while a heavy steel head pivots from a position near that of the frame and is counter-balanced in a similar manner. The front of the head carries a steel hook, spring tensioned to afford a grip in a recess on the front of the cylinder casting. The mould ram is hydraulically operated. The underside of the head is made of brass which metal, being smooth and rustless, is less likely to cause sticking of the meal to the head.

Operation

To operate the mould, a piece of press cloth is placed upon the mould table. The frame is pulled down on the table in a horizontal position, whence its left side surface is level with a strickling box table under the base of the cooker, or meal kettle. The strickling box contains a charge of hot meal and is drawn out across the frame. The base of the strickling box is open and the meal is deposited in the space of the mould frame. The forward movement of the box closes the opening from the cooker and the return movement again opens the cooker cut off to allow the next charge to fall into the box.

The mould head is then pulled down and secured by the hook and hook plate. The head fits neatly into the rectangular

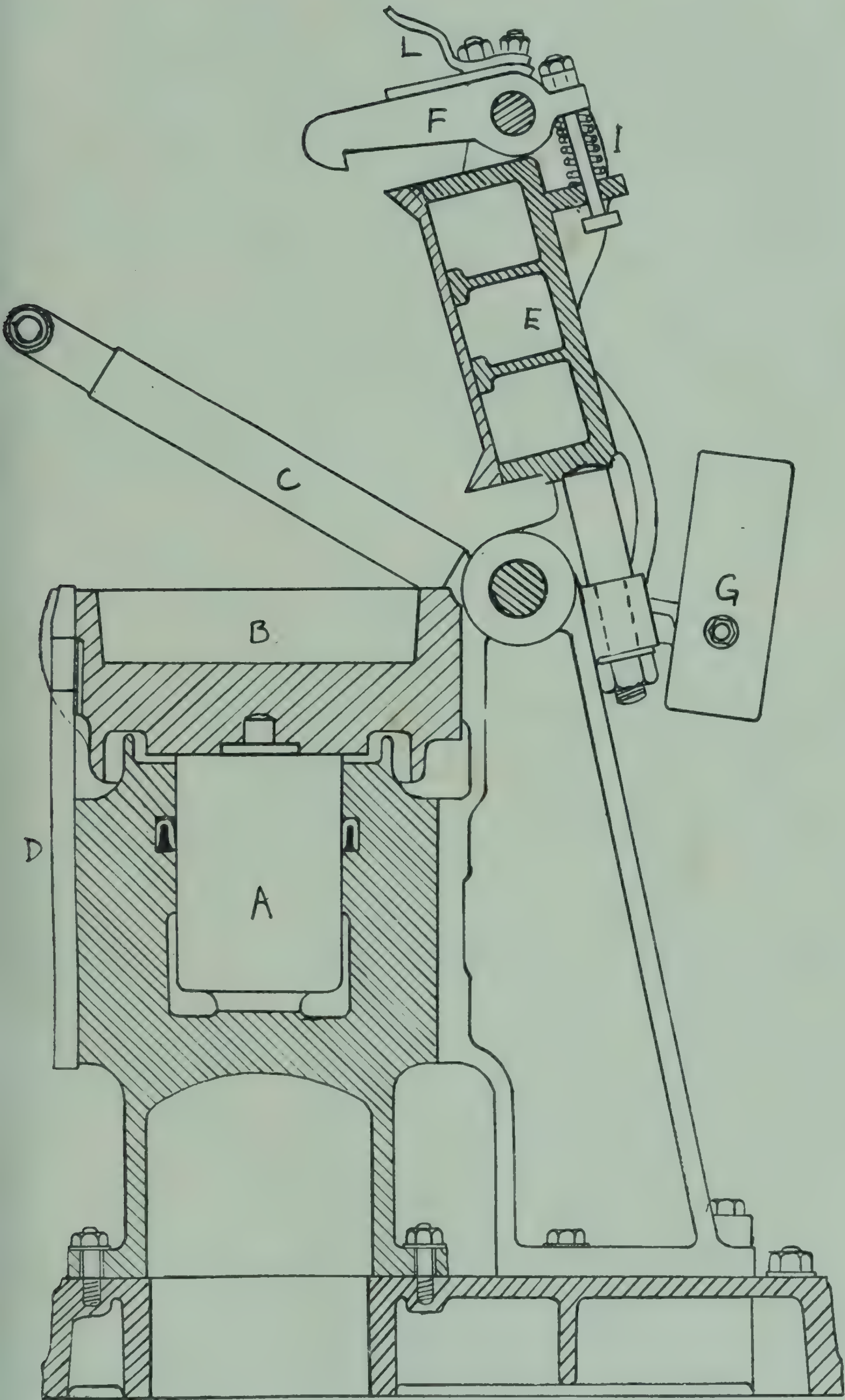


Fig. 1 Sectional Elevation of Manual Mould

A Hydraulic Ram.
B Table, Cake Box
C Frame
D Hook Plate (see also Fig. 2)
E Mould Head Casting
F Clamping Hook
G Counter Weight for Frame
H Hydraulic Control Handle (Fig 2)
I Hook Tension Spring
J Pressure Oil Inlet (Fig. 2)
K ,, ,, Outlet (Fig. 2)
L Hook Release

space inside the frame carrying the charge of meal. An upward pull on the handle controlling the supply from the hydraulic system causes oil to enter the cylinder and the ram and table immediately rise, the meal being pressed against the mould head; pressure is maintained for a few seconds and then released by dropping the control handle to the release position. The ram, table and newly moulded cake now drop back to the original level, while the frame and head are lifted clear by an upward pull on the front handle of the frame by the operator.

The press cloth is folded over the cake, a tray is inserted by the press filler, under the cake, which is lifted clear of the mould table and inserted in one of the spaces between the plates of the press under charge. The sequence is again repeated for the succeeding cakes and carried on until the press is filled.

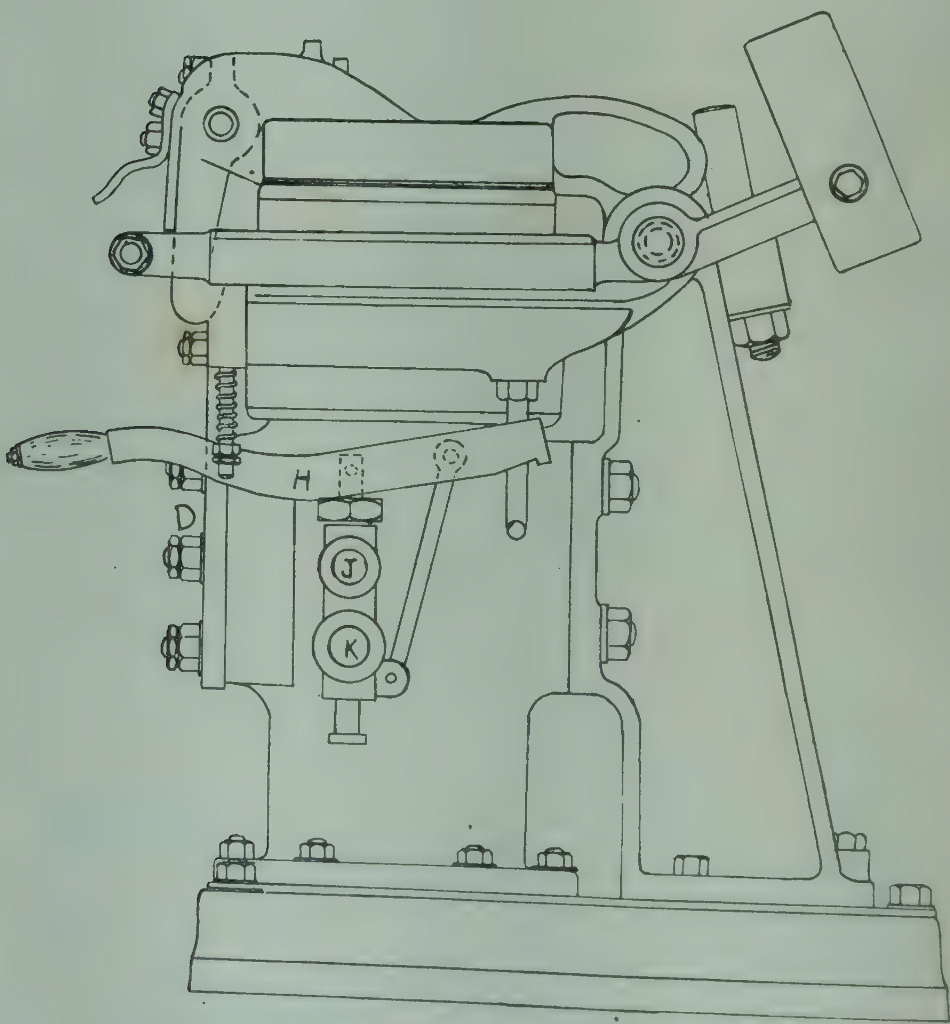


Fig. 2 Mould Head closed with hook in position

Points in the Operation

The pressure applied to the mould should be sufficient to compress the meal into a well formed cake, but not sufficient to start the oil flow. The distance travelled by the ram is about one inch since the cake undergoes a reduction in volume while being pressed in the mould.

The depth of the unpressed cake will vary, but should approximate $3\frac{1}{2}$ inches. A one inch reduction of depth equals 29 per cent. reduction in volume.

The diameter of the mould ram is nine inches and the pressure is supplied from the low pressure system, i.e., 700 lb. per square inch. The actual pressure applied to the cake meal, therefore, can be calculated :

$$\text{Area of cake } 34 \text{ in.} \times 13 \text{ in.} = 442 \text{ sq. inch}$$

$$\text{Area of ram } \frac{\pi D^2}{4} = \frac{22}{7} \times \frac{9 \times 9}{4} = 63.6 \text{ sq. inch}$$

Pressure per square inch applied to cake=

$$\frac{700 \times 63.6}{442} = 100.7 \text{ lb. per sq. inch}$$

100 lb. per sq. inch is, of course, nothing like sufficient to start the oil from most types of oilseed meals, but is enough to produce a well formed cake for pressing.

The tray used for carrying the cake should be as light as possible, in order to reduce the effort on the part of the press filler. A tray made of duralumin will give the best performance for the type of mould described. The dimensions of the tray are 34 in. × 13 in. × 14 gauge, and its weight is about 5 lb.

Fig. 1 shows a sectional elevation of a manual mould with the head raised, while Fig. 2 shows the mould head closed and the hook in position.

The counter-balance weights for easy manipulation of the mould head are not shown on the drawings, but they function in the same manner as the balance weights of the frame (G).

Automatic Hydraulic Cake Mould

The automatic mould is an improvement on the hand type for two distinct reasons :

(a) Physical effort is considerably reduced.

(b) Greater uniformity of cake moulded.

The reasons for the above advantages will be appreciated best when the operation of the mould has been described.

The strickling box and piston are shown above the box control handle in Fig. 4. The tube housing the piston which projects the strickling box on its forward movement runs the

length of the structure. This movement is explained at the end of the lecture by means of the box control valve diagram.

A piece of press cloth is placed on the mould table in the same manner as previously described for the hand mould, and the frame is pulled down on to the table. The strickling box under the cooker, which is charged with meal, is then moved forward over the mould in the manner described at the end of the chapter.

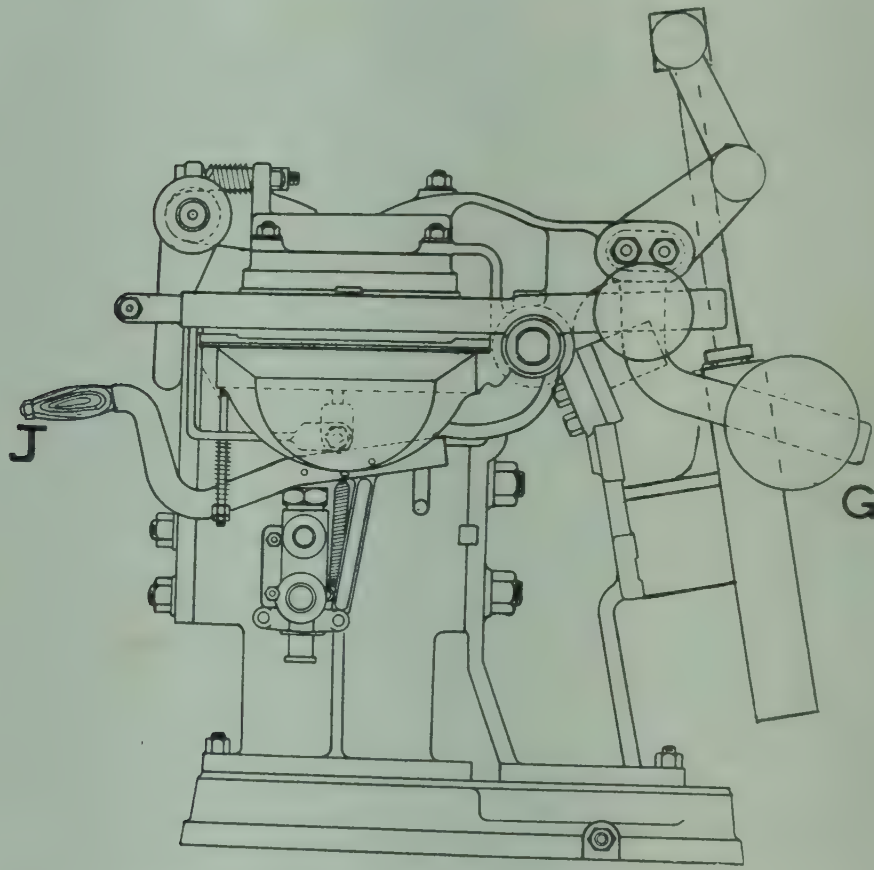


Fig. 3

(G) Head Balance Weight. **(J)** Mould Piston Control Handle

When the box control handle is released, a spring tension device at the back withdraws the spindle and the box moves back to its position under the cooker. When the strickling box first commences its forward movement, a slide is automatically pulled across the orifice in the cooker base to prevent the meal leaving. On the return of the box, the slide is pushed back from the orifice to allow the box to fill up for the next charge. The mould bed and frame now hold a charge of material sufficient to produce one moulded cake.

The mould head is now brought down by the following operation:

The lever handle controlling the oil inlet at (P) is raised to its top position and the piston of the head control valve is

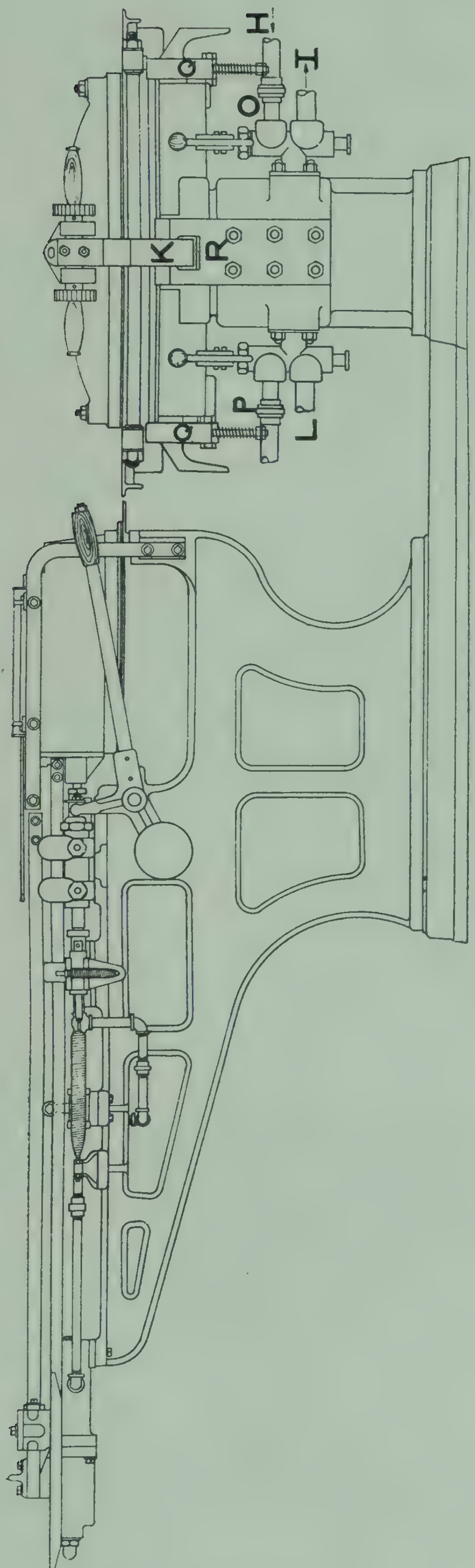


Fig. 4

(H) Oil Inlet Mould Control Valve
(I) Oil Outlet Mould Control Valve
(K) Clamping Hook Mould Head
(L) Oil Outlet Head Control Valve
(O) Mould Ram Control Valve
(P) Oil Inlet Head Control Valve
(Q) Mould Head Shock Absorber
(R) Hook Plate

raised with it. The narrow neck of the piston is brought opposite the oil inlet (P) from the pressure oil supply pipe and oil flows into a cylinder mounted on the back casting of the mould structure. The piston in the head cylinder is thereby raised, and by its linkage with the head, the head is dropped into place over the mould table. At the same time, the clamping hook (G) springs into a cavity on the hook plate (R) (Fig. 4).

The control handle is allowed to drop back to its original position, but the mould is kept in place by means of the hook. The handle (J) (Fig. 3) is now raised and oil enters the main cylinder of the mould by means of the inlet (H) (Fig. 4), and the mould piston rises and exerts its full pressure against the table and cake. The valve mechanism is identical with that described in closing the head. The pressure is held for a few seconds and then released.

The cake has now been moulded to a neat, uniform mass and the head and frame are lifted clear by means of a light pull on the bar of the mould frame. The remainder of the operation is similar to that described for the hand mould.

Control Mechanism of the Strickling Box

When the mould is at rest, a permanent supply of pressure oil holds the strickling box under the cooker opening by means of the pathway (A) (Fig. 5) and the cylinder (B). The pressure is exerted on an annulus formed by the piston shaft and the piston head surface at (C). While the position is held, the piston surface (D) on the opposing side receives no pressure, since the cylinder (E) is opened to the exhaust pipe (F). The control piston (G) is held in the position shown on diagram by means of a powerful spring.

To move the strickling box forward, the operator depresses the control handle and the control piston moves forward to the position indicated by the dotted lines. This movement immediately closes the exhaust pipe and allows pressure oil to flow in the cylinder (E).

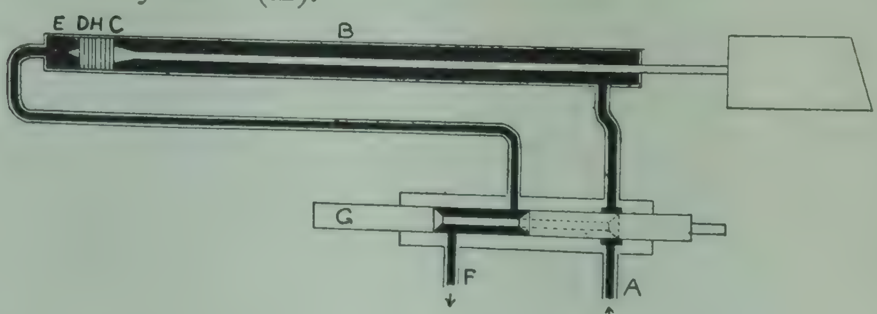


Fig. 5

(A) Pressure oil inlet
(B) Box Control Cylinder
(C) Right Piston Face
(D) Left Piston Face
(E) Opposing Cylinder
(F) Exhaust
(G) Control Valve Spindle
(H) Piston Head

A force of 700 lb. per square inch is now exerted on both faces of the piston (H). It will be noted, however, that the pressure in the cylinder (E) is operating against the full area of the piston head as compared with the annulus at piston surface (C). Since the greater pressure is exerted on the surface (D), the piston is pushed to the right and the box moves forward over the mould frame. At this position, it may be wondered what happens to the oil in the cylinder since there is no obvious way out. The exhaust oil from the cylinder joins the flow into the opposing cylinder (E). The volume of oil taken into cylinder (E) is greater than that which is ejected from cylinder (B). The volumetric difference is due to the piston shaft running through cylinder (B). The operator now allows the control handle to spring back into the rest position and the valve spindle (G) returns to the original place shown on the diagram. The cylinder (E) is automatically opened to exhaust, and the inlet supply of pressure oil cut off. There is now no opposing pressure to resist that exerted in cylinder (B), and the piston and box shoot back immediately to the position on the left, as shown on the diagram.

CHAPTER II.

THE CAGE PRESS

The main purpose of the cage press is the initial crushing of seeds, containing a considerable amount of oil. Most types of high oil content seed require more than one pressing. When the necessary conditioning, i.e. rolling and cooking, has been carried out, the seeds are of a consistency which tends to spread badly if crushed in an open press of the Anglo-American type.

The chief difference between the Anglo-American press and the cage press is that the latter is fitted with a special containing device commonly known as a cage, hence its name. The purpose of the cage is to hold the meal securely while pressure is applied and, at the same time, to allow the expressed oil to escape. There are many different types of cage press but they differ from one another mainly in the cage assembly and also in size.

For convenience, the press assembly may be divided into three main sections :

(1) Press head, feed and discharge.
(2) Cage and meal chamber.
(3) Base housing ram and cylinder.

The second or central section will be described first, since it can be regarded as the connecting link between the sections (1) and (3).

The Cage

The cage may be designed to press either circular or square shaped cakes. The circular type of cage consists of a series of

strong steel bars which are recessed into a top and bottom steel casting. The bars are T-shaped in section, the long leg of the T resting against the inner wall of the top and bottom castings which have been formed by boring central holes in each. The cross bar of the T is very narrow, becoming a mere fillet at the inner end of the bar section. The fillet is recessed at intervals on one side so that when the bars are resting against each other, the recess becomes a slot which allows the oil to escape when the meal is under pressure.

The top and bottom castings are secured to each other by means of three or four tie rods, according to the particular design of the press. The bars are supported by a series of weldless steel rings which are fixed at intervals on the outside of the cage and held in position by means of distance pieces or ferruls on the tie rods. The meal chamber or cylinder thus formed is ground to ensure a smooth bore for easy movement of the meal when under pressure, to ensure a neat fit for the head of the ram which is described later.

The method of mounting the cage on the base casting varies with different manufacturers, but two important points have to be taken into account. The cage must fit in correct alignment with the press cylinder and at the same time be free to perform a limited upward movement when pressure is applied. One method of obtaining these two points is the inclusion on the top and bottom cage castings of four ears concaved to fit neatly between the four columns which connect sections (1) and (2).

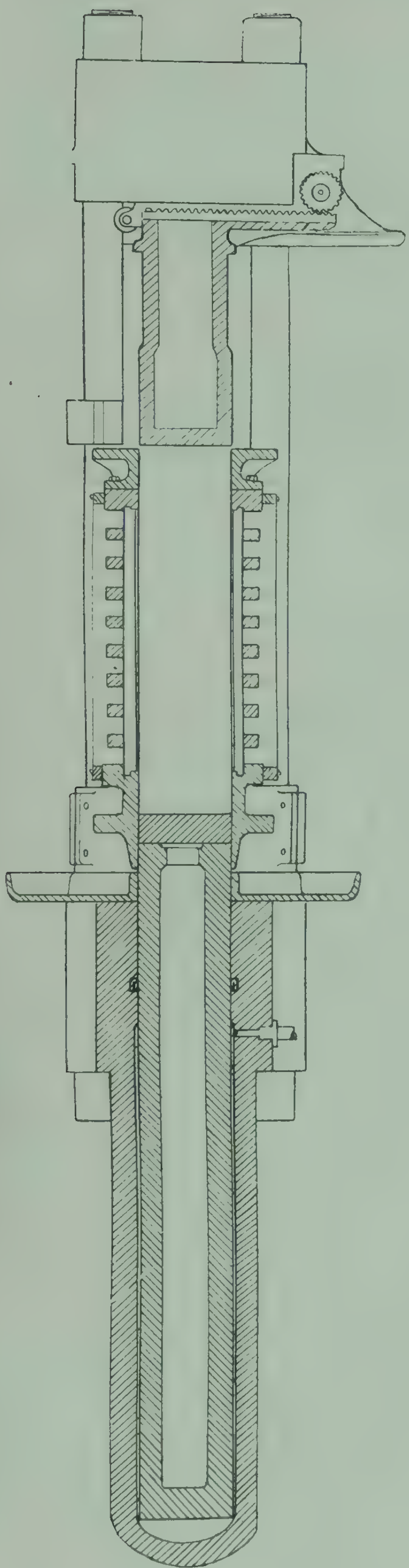
Head Section

The head is made of cast steel and bored at the corners to accommodate the columns which connect the head to the base casting. The underside of the head is some distance above the top level of the cage, and a ram extends from the head to the cage opening.

The ram is capable of horizontal movement only and is operated by means of a rack and pinion when its removal is necessary. The base casting carries the cylinder which houses the hydraulic ram, and this casting usually includes a tray for catching the expressed oil.

The hydraulic ram is a comparatively neat fit in the cylinder near the top, but an increase in clearance takes place in the lower section of the cylinder. The oil inlet, for pressure application, is situated in that part of the cylinder where the greater clearance is allowed. The U-leather, to prevent leakage, is recessed in the upper section of the cylinder.

The weight of the cage is taken by four split muffs fitted on the press columns, the four concaved ears mentioned earlier resting on the muffs. The base carries two small hydraulic jacks



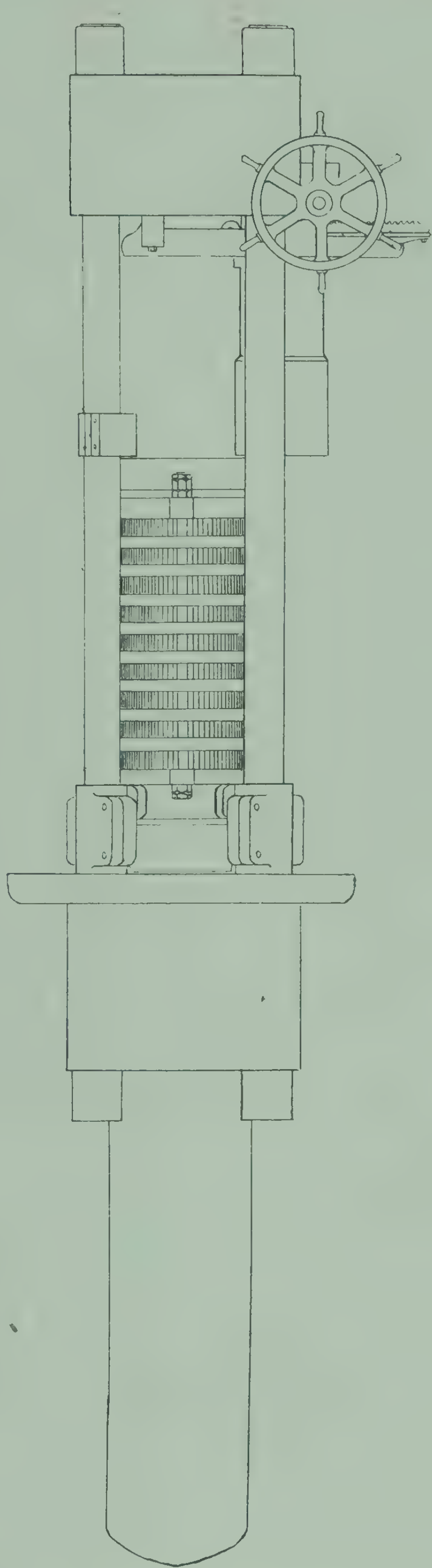


Fig 6.

Sectional view of Cage Press with movable head over cage.

View of Cage Press showing Movable head in retracted position.

which are capable of lifting the cage vertically a distance of about six to nine inches.

The diameter of the cage is larger than the diameter of the main hydraulic cylinder, and whilst the lower portion of the ram is a neat fit in the cylinder, a top cap of larger diameter is fitted to operate inside the cage with a minimum of clearance. The depth of the top cap is about three inches, and its shallowness thus affords a minimum frictional surface against the inside wall of the cage.

Operation of the Cage Press

The presses are usually mounted in pairs and fed from a single cooker. The largest types, however, are fed from independent cookers. The method of feeding and also of mounting the cookers may take one of two different forms. The first method requires that the cooker be situated on the top of the press and the meal supplied via a hole in the press head. The volume formed by the hole contains a correct charge of cooked meal, when filled, for one cake. The second method requires that the cooker be mounted near the head of the press and the strickling box under the cooker has its base in line with the cage top.

When the press is to commence work, the operator applies low pressure to the main cylinder and the ram rises up the centre of the cage to a point near the top. A steel plate is placed on the top of the ram, followed by a circular press cloth. A charge of meal sufficient for one cake is now tipped from the strickling box into the cage and this is followed by another press cloth. Meanwhile, the pressure oil control is set to slow exhaust so that the ram is allowed to drop very slowly. As the second press cloth drops away from the top of the cage, another steel plate is placed in the cage, followed by another press cloth. A second cake is then moulded and the sequence described above is repeated. The filling of the press is complete when the ram reaches its lowest position and the last cake is stationary at the top of the cage.

The movable head is now run directly over the cage orifice to prevent upward movement of the top cake. The hydraulic jacks situated under the cage base are now brought into action by the application of low pressure oil into their cylinders. This causes the cage to rise from its seat six to nine inches. The top of the cage, on rising, passes above the lower face of the movable head and so ensures maximum seal between cage and head.

All is now ready for the pressing process and hydraulic low pressure is again applied to the main cylinder. The upward movement of the ram commences to compress the cakes, and as

the pressure increases, the ram movement slows down. Oil commences to flow slowly from the slots in the cage at this stage. The operator then alters the hydraulic flow from low pressure (700 lb. per square inch) to high pressure. This may be two to three tons per square inch, according to circumstances and equipment. A more copious oil flow is noticed almost immediately as well as a further travel of the ram.

The upward movement of the ram and cake takes the cage upwards for a small distance. This is both necessary and advantageous as it affords a more even distribution of pressure on the cake throughout the whole length of the cage by easing the grip on the cage by these cakes which are receiving the first effects of the hydraulic pressure.

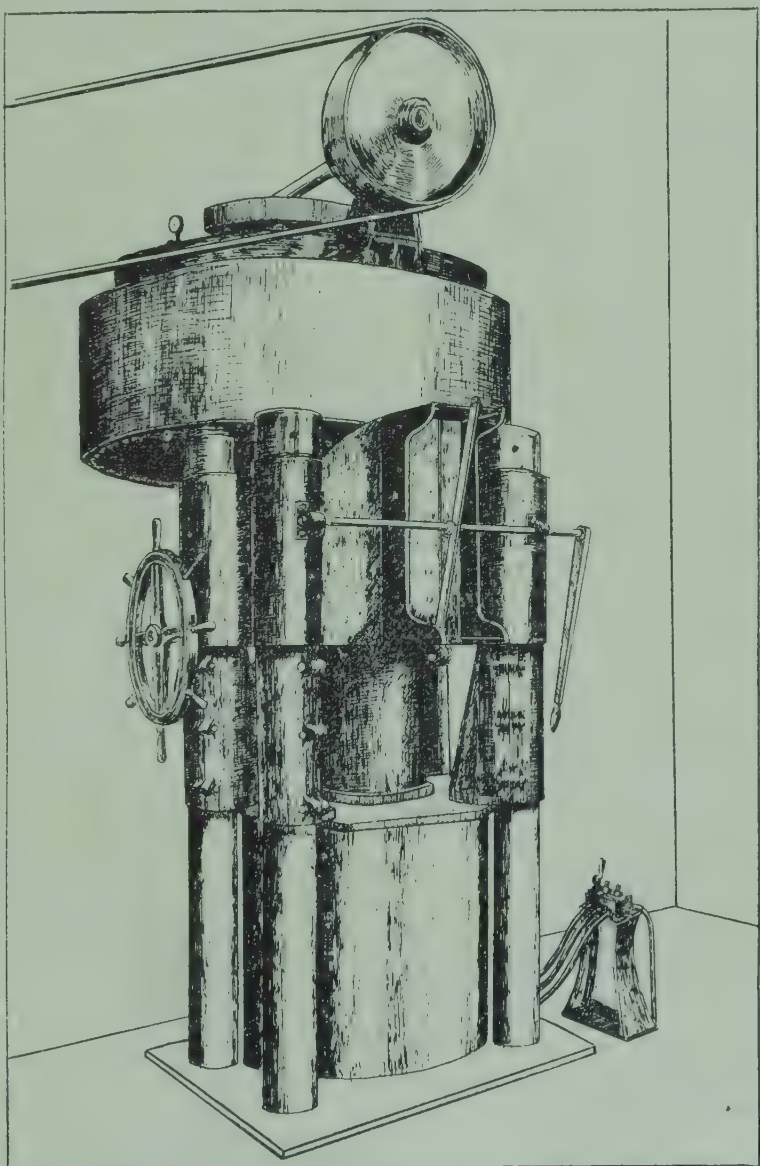


Fig. 7 One of the largest types of Cage Press showing cooker mounted on top of the head

The press is kept under pressure for 20 to 30 minutes, after which period it is judged that pressing is complete and the flow of oil from the press has ceased. The next operation is the removal of the cakes from the cage. To do this, the main and jacking cylinders are allowed to exhaust, and cage and ram slowly drop downward, the cage coming to rest on the muffs on the press columns. The movable head is then moved clear of the cage orifice, but not quite clear of the cage top—the columns on the opposite side are fitted with muffs which are now swung round to stop the cage in conjunction with the movable head from moving upwards. Pressure is again applied to the main ram and this time, since there is now no resistance to the upward movement, the cakes are slowly ejected.

Details of Performance

It will be noted that in the case of Anglo-American presses, the meal in the moulding operation suffers a considerable reduction in volume which has the effect of increasing the capacity of each press charge. The cage press, however, is charged with meal at its normal density and in consequence of this, the meal charge per press is considerably reduced. This disadvantage is sometimes overcome by applying a preliminary compression to the cakes in the cages, followed by the opening and further filling of the press due to the gain in cage space from the initial compressing. At the same time, this further operation requires additional time for its prosecution and the addition to the press mechanism of a device for fixing the cage to the ram. The finished cakes, however, are of neat appearance without oily or broken edges. The paring operation so necessary with Anglo-American processing is therefore obviated.

The capacity of the press depends upon its size—the largest types use a ram of about 18½ inches diameter, producing a cake of similar diameter. Hydraulic pressure of three tons per square inch is applied to presses of this size, imposing a total pressure on the cakes of 806 tons.

The pressing capacity is also influenced by the type and density of the material under treatment. The press described above will treat about five cwt. of meal per crush and at, say, two charges per hour, the production per press is approximately 10 cwt. per hour. The actual pressure applied to the meal is much greater in the case of the cage presses than that applied in Anglo-American pressing, even though the pressure per square inch on the hydraulic fluid be the same, say, two tons. This is because the area of the ram is almost identical with the cake area, whereas a cake produced in an A.-A. press has an area almost twice the ram area resulting in a halving of the pressure application in terms of lb. per square inch.

The cage press is undoubtedly more suitable for crushing high oil content seeds, particularly those which tend to spread when in an open press. Because of this, the pressing may be carried out in two operations involving the reduction and rolling of the first stage cake meal for the secondary crush.

When cage presses are worked in pairs, they are operated alternately in order to make the most economical use of both labour, pressure and oil production. The cage press is suitable for the treatment of copra, groundnuts, castor seed, palm kernels, babasoo kernels, and sesame. Certain of these seeds, however, require much smaller orifices in the cage than others, notably groundnuts, sesame seed and castor. This is because the softer consistency of these makes them tend to work through the cage bars with the oil.

CHAPTER III.

COOKING KETTLES AND COOKING

Broadly speaking, the pressing of oil seeds falls into two classes :

(a) Cold pressing.
(b) Hot pressing.

It has been established beyond doubt that the best possible quality of oil is that removed in the cold pressing process. Cold pressing, however, has certain distinct disadvantages. At atmospheric temperatures, most types of oil are viscous, if not actually of hard consistency. For this reason, the oil will not run easily from the meal and a comparatively small percentage of the total oil is removed, despite application of very high pressure. The small oil yield makes the process very expensive. Rolling of seeds does not always succeed in rupturing all of the oil cells. Furthermore, the protein in the seeds being soft and yielding, there is a tendency for their removal with the oil. In all cases of cold pressing, a subsequent hot pressing is necessary in order finally to remove the maximum possible oil.

Hot pressing is by far the more common process, since the disadvantages obtained by use of this method are outweighed by the advantages :

(1) The application of heat reduces the viscosity of the oil which expedites its removal when under pressure.
(2) The oil cells which are not broken in the Anglo-American rolling process are weakened or broken in the cooking, resulting in the partial freeing of the oil for removal in the press.
(3) The albuminous material or proteins are partially coagulated and there is, therefore, less tendency for them to be liberated with the oil.

The nett result of the three points mentioned is that the maximum possible oil yield is obtained in the pressing process.

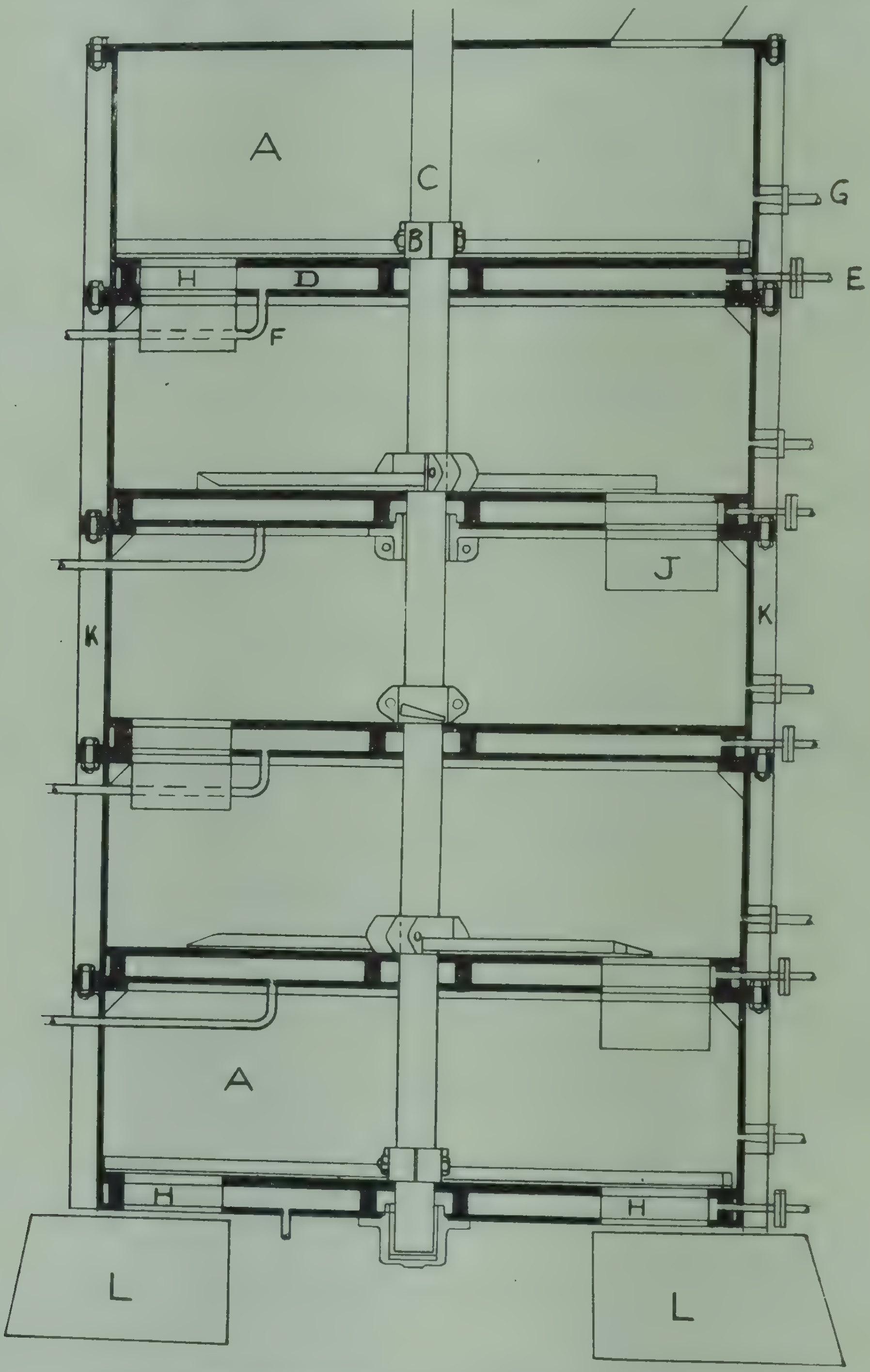


Fig. 8 **Details of Sectional Diagram of Five-Stack Cooker**

(a) Meal chambers. (b) Stirrers. (c) Carrier shaft for stirrers. (d) Steam chambers. (e) Steam inlet. (f) Condensate outlet to steam trap. (g) "Live" steam jets. (h) Meal exit holes to lower chamber. (j) Box on meal exit. (k) Asbestos insulation. (l) Strickling boxes.

It must be mentioned, however, that certain disadvantages are obtained from hot processing. Many types of seeds contain colouring matter, both in the fleshy oil bearing kernel and/or in the shell. Certain seeds are crushed with the shell partially or wholly present and the colouring matter from both the flesh and the shell are dissolved in the oil during the heating process. The colouring matter is fixed more firmly in the oil by the application of high temperature, thereby increasing the refining problems. This, however, is a subject for further study at a later date.

The Cooking Kettle

Hot pressing requires the use of a cooker or heating vessel and the cooker may consist of 1, 2, 3, 4 or 5 chambers, depending upon the ideas of the particular technician and upon the class of seed being processed. Fig. 8 shows a sectional view of a five-chambered (sometimes referred to as five-stack) cooker.

The chambers are made of steel, usually about $\frac{3}{4}$ inch to 1 inch thick. The base of the chamber is a hollow disc of either cast iron or riveted steel plates. Steam is applied to the base chamber and, since the steam cannot directly contact the meal, this type of heating is known as dry or jacket heat. A central shaft driven by means of a pinion wheel carries a double stirrer or agitator in each chamber and travels at about 60 r.p.m.

The meal is fed into the top chamber by means of a chute and is agitated or stirred. The base is equipped with one or two exit holes through which the meal is allowed to drop into the chamber below; the exit holes in the next chamber are in positions which are at right angles to the holes above. In this way, the meal is allowed to make its way slowly down to the final chamber, then in to the strickling boxes which charge the cake moulds. It is often necessary to apply steam direct to the meal, and in some cases water may be added. Direct steam application is referred to as "live" steam, as distinct from "jacket" steam.

Each exit hole in the chamber is equipped with a cut-off device or flapper which limits the height of the meal in the chamber. If this device were not fitted, the meal would tend to concentrate too quickly into the lower chambers and pack so tightly as to stop the cooker.

The purpose of the five-stack cooker is to provide the optimum area over which heat can be transmitted to the meal. In some cases, steam jackets may be fitted to the sides of the chambers in addition to the base jackets. The outer surface of the meal chambers is covered with a layer of insulating material enclosed within a sheet metal casing. The insulating medium is usually asbestos "wool." Where the cooker is not fully insulated, the heat loss due to radiation is heavy, and in

consequence the cooking cost is unnecessarily high. Each chamber has a strong steel door covering an opening which will admit a man. This is necessary for the purpose of cleaning and repairing.

Where the heat transmission area is insufficient, a lower temperature will tend to obtain in the cooked meal, and to offset this a slower working speed must be allowed. High temperature steam tends to create excessive heating of certain parts of the meal, resulting in burning or discolouration. The steam is applied to the jackets at about 60 lb. pressure per square inch and at a temperature of about 307 degrees F. The temperature of the cooked meal will vary a good deal with the different types of seed being processed, the usual range for most types of seeds will be between 170 and 220 degrees F. Each steam chamber exhausts into a trap and the condensate is led away either back to the boilers or to waste.

A five-stack cooker of 6 ft. 6 ins. diameter is capable of heating most cake meals to 200 degrees F. at a rate of 4 tons per hour, but, of course, this figure is influenced by the proportion of live steam heating, type of material and efficiency of insulation against radiation loss.

The heat imparted to the meal consists almost entirely of that which is given up in the process of condensation. This heat is given up without any drop in temperature between steam and resultant condensate and is known as the latent heat of condensation.

Cooking

As a source of heat application to seed meal under process, steam is generated at the boiler house of the factory and is passed on to the consuming departments by means of distributing ducts or pipes. When the system is complicated by a complexity of demand from many processing departments, the problem of distribution requires special treatment by experienced steam engineers. Their problems need not concern us unduly, as the chief concern of the seed crushing operator is the form or nature of the steam on arrival at the point of usage. At the same time, there are some aspects of steam distribution, a knowledge of which is useful to the consumer.

The higher the pressure at which the steam leaves the boiler house, the smaller the volume occupied by unit mass. This allows the largest possible flow of steam through a pipe of economical size. The pressure generated may be as high as 200 lb. per square inch or even higher at the source and the temperature will be proportionately high.

It is not desirable that steam at a very high temperature be supplied to the cookers, and the pressure in any case is far greater than most of these vessels are designed to accommodate.

To prevent this, a reducing device is included in the equipment of the cooker steam lead in. The reducing valve, as it is called, can be set to pass steam at pressures far below that in the main pipe feed. Most cookers operate at steam pressures of 50 or 60 lb. per square inch, and the temperature of saturated steam at this pressure is about 307 degrees F. This temperature is high enough to give an efficient heat transfer but is not likely to cause scorching due to intense local heating. The mass of seed meal entering the top chamber of the cooker is very probably at atmospheric temperature, and although this temperature varies from day to day, we may be safe to assume that it averages about 60 degrees F.

The condition now arises when a mass of meal at 60 degrees F. is resting on the top surface of the steam chamber and steam is entering the chamber at 307 degrees F. The large disparity in the temperature causes a rapid transfer of heat to the meal, the temperature of which commences to rise. At the same time, the loss of heat by the steam causes condensation in the steam chamber and the latent heat stored in the steam is passed on to the meal via the chamber surface.

If condensation takes place at 60 lb. per square inch, the latent heat given up by one pound of steam changing to one pound of water will be about 905 B.T.U. The water produced drains away from the chamber at 307 degrees F., via a steam trap, which will be described later. Whatever pressure may exist on the pressure side of the trap, the discharge side will naturally be at atmospheric pressure.

The release of pressure on the water immediately has the effect of converting some of the water back to steam at 212 degrees F., i.e., the temperature of the water at atmospheric pressure. The steam produced is known as flash steam. Unfortunately, unless the heat in the water and flash steam can be utilized for some other purpose, its heat value is wasted and the only heat which has been made use of in the cooking process is the latent heat of condensation. The case of live or direct steam is somewhat different, where, in addition to the latent heat imparted to the meal, a certain proportion of the sensible heat is also used since the condensate soon reaches equilibrium with the meal in the cooker.

The amount of jacket steam used per unit period can be approximately determined with little calculation in the following manner : The condensate exhaust pipe is disconnected from the main exhaust pipe and is inserted by means of a swivel pipe into a fairly large vessel containing water. The condensate will flow from the trap down the exhaust pipe and into the container. The increase in the amount of water for a given period will show the rate of condensation. Naturally, live steam is not recoverable and therefore cannot be measured in the manner

described. Its measurement would require special instruments in the hands of skilled technicians and therefore a certain amount of assumption would be necessary.

It is in the interests of the steam user to know at least approximately if usage is wasteful or inefficient where the operator is desirous of determining the heat transfer efficiency of his cooking equipment. It may be that steam consumption

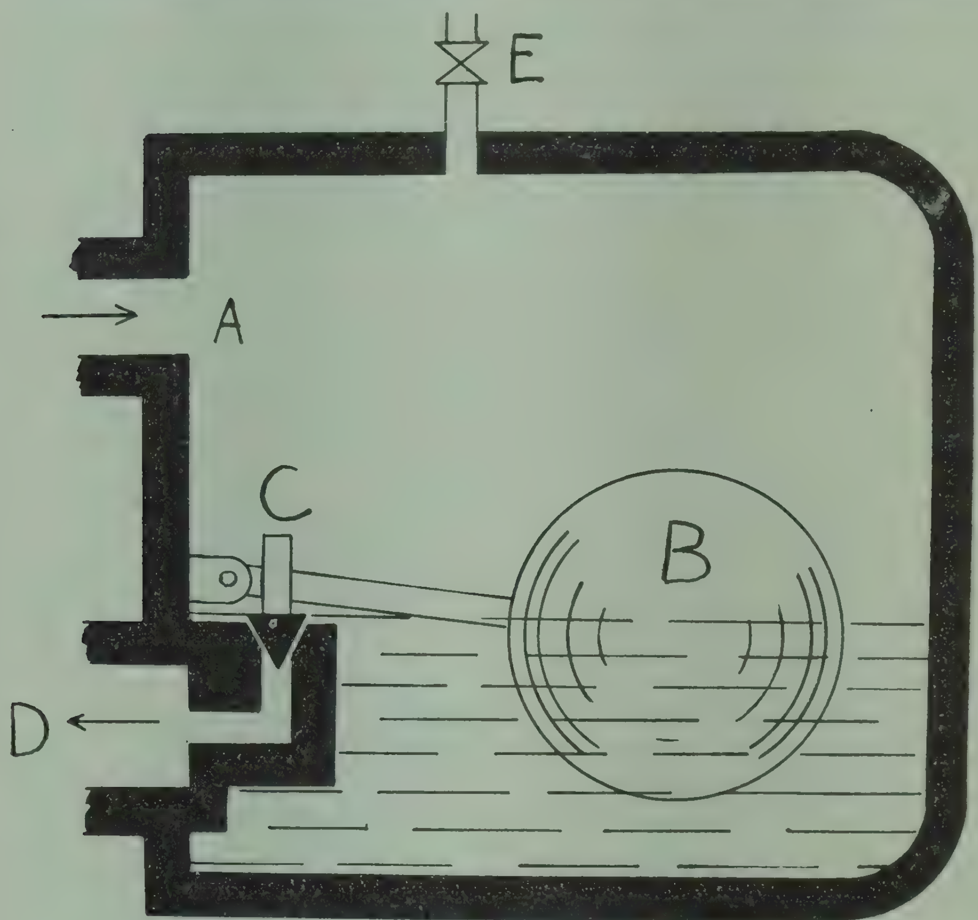


Fig 9. Section of Steam Trap

has been recorded by instruments and he is anxious to compare it with the theoretical consumption at maximum efficiency. It is necessary, of course, to know just how much heat is required by the material under process, and this can be determined in the following manner:

To heat one ton of seed meal at a specific heat 0.45 from 60 degrees F. to 200 degrees F.

Total heat required = Mass × sp. ht. × T degs. rise F.
= 2,240 × 0.45 × (200 − 60)
= 141,120 B.T.U.

Assume steam usage is 25 per cent. live steam and 75 per cent. jacket steam. Find amount of steam required to impart 141,120 B.T.U. to seed at 100 per cent. efficiency.

Steam supply 60 lb. per sq. in. at 307 degrees F.
1 lb. live steam at 307 degrees F. changes to water and drops to 200 degrees F. Heat given up by 1 lb. steam = Total heat minus heat required to raise temperature of water from 32 degrees F. to 200 degrees F.

$$= 1{,}183 - 168$$
$$= 1{,}015 \text{ B.T.U.}$$

3 lb. jacket steam gives up its latent heat only

$$= 3 \times 905$$
$$= 2{,}715 \text{ B.T.U.}$$

Average amount of heat given up by 25 per cent. live and 75 per cent. jacket steam

= 1 lb. live steam	1,015 B.T.U.		
3 lb. jacket	2,715		
4 lb.	3,730	= 932 B.T.U. per lb.	

Steam consumption at 100 per cent. efficiency

$$= \frac{\text{Total B.T.U.}}{\text{B.T.U. per lb. steam}}$$
$$= \frac{141{,}120}{932}$$
$$= 151.4 \text{ lb.}$$

Actual meter reading for above work would probably be 210 lb. steam per ton of seed meal.

$$\text{Efficiency } \therefore \quad = \frac{151.4 \times 100}{210}$$
$$= 72.1 \text{ per cent.}$$

The calculation given is necessarily approximate and only refers to steam behaviour after delivery to the cooking kettle.

The temperature and latent heat of steam at the pressure stated is found in Steam Tables.

Steam Traps

There are many types and designs of steam trap but they differ chiefly in the mechanical ingenuity of the designer. The general function is the same for all types.

The purpose of the trap is to ensure that water only will flow from the condensation chamber and that any steam which has escaped without giving up its latent heat shall not pass to the waste pipe.

The condensate enters the trap chamber via the inlet (A) (Fig. 9) and falls to the bottom. As the quantity of water rises, the ball (B) is floated and the security arm lifts. When the water covers the valve (C), the ball has raised the arm sufficiently to lift the valve off its seating and the water flows to waste or to a

collecting tank via (D). Should steam only enter the chamber, it cannot affect the position of the ball and the valve, therefore, is closed.

The trap cannot function properly if air is present and it may be necessary therefore to release air when the trap commences to work. The valve (E) is then opened, the air released and the valve closed again. Some traps are designed to expel air automatically and information on this subject can be obtained from text books on steam usage.

CHAPTER IV.

HYDRAULIC PUMPS

Most hydraulic pumps are of the reciprocating variety and may be either of horizontal or vertical throw. Like many other machines in the seed crushing industry, they vary considerably in size and design. The main principles, however, are fairly similar for most types.

Previous chapters on hydraulic pressure showed that a fluid, preferably oil, is pumped into the press cylinder and exerts enormous pressure on the ram. It was also stated that the initial closing pressure was 700 lb. per square inch, while the final or high pressure was 2 tons per square inch, or in the case of a large cage press, high pressure fluid flow at 3 tons per square inch was used.

To produce these enormous pressures, special pumps of powerful and intricate construction are used.

Vertical Four Throw Pump for High and Low Pressure

This pump (Fig. 10) is equipped with two low pressure pistons 4 inches diameter (A) and two high pressure pistons 1½ inches diameter (B) with a stroke of 6 inches. The main pump shaft is carried between two strong iron pedestals and is a solid steel forging which gives the maximum strength and avoids the possibility of the eccentrics becoming loose.

On each eccentric a revolving arm with gun metal bearings is linked to a piston. About the point of linkage the piston is rigidly housed by the guide bracket (D), thus ensuring a perfect vertical movement. The two low pressure pistons (A) and the high pressure pistons (B) are turned from solid steel and are a perfect fit in their cylinders. The pistons are set in the centre of the cylinder and guide boxes (C). The outlet for the pressure oil is shown top centre of the piston and valve boxes.

The inlet and outlet valves are of the mushroom type and are shown in the sectional view of the box. The speed of the

main pump shaft is 55 to 60 r.p.m. The design of the eccentric or main pump shaft is such that each piston is performing a different phase of the complete function at any given time. This ensures the maximum evenness of strain on the driving unit.

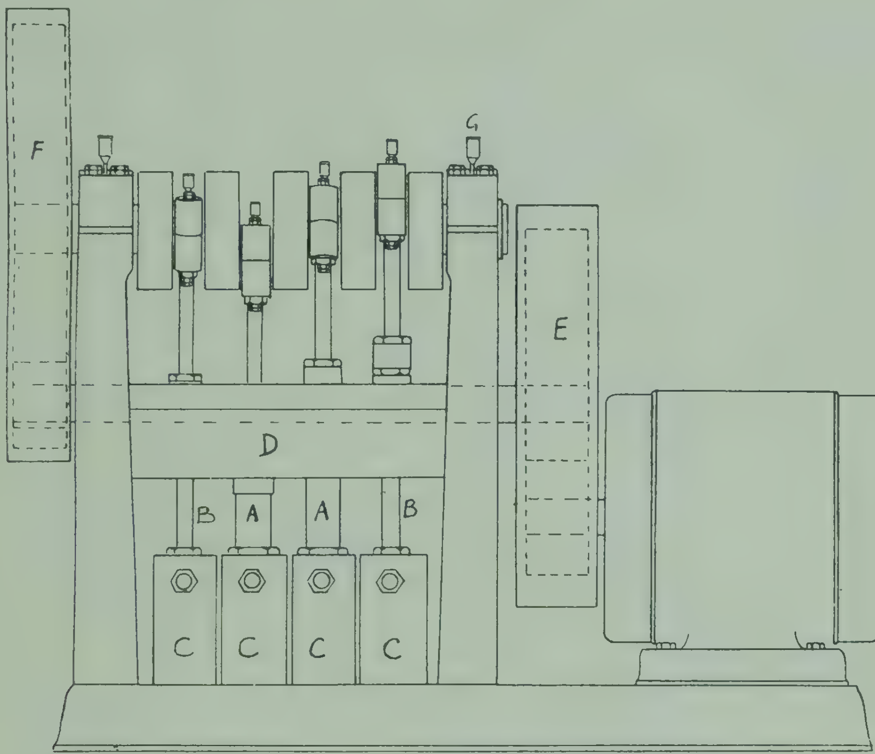


Fig. 10 Hydraulic Pump

(A) Low pressure pistons. (B) High pressure pistons. (C) Valve and piston boxes. (D) Guide bracket. (E) Helical or chain drive, motor to counter shaft. (F) Helical or chain drive, counter shaft to pump driving shaft. (G) Oil lubricators.

Driving Unit

Various methods of driving may be used. The diagram shows the arrangement for an electric motor drive. The motor is 40 h.p. and carries a small double helical gear which meshes with a much larger wheel (E) on the intermediate or counter shaft mounted on bearings which are supported by the iron pedestal. This gives a reduced speed to the counter shaft. At the other end of the shaft, a small double helical wheel meshes with a large wheel on the eccentric shaft. This last transmission provides the final step down to the pump speed of 55 to 60 r.p.m.

The solid bearings require efficient lubrication and this is provided by the grease cups (G). Each pump arm carries its own grease cup as also does the pedestal bearings.

It is usual to include a relief valve in the pressure supply line in order to ensure that the stated maximum pressures cannot be exceeded. The relief valve is loaded to lift when the

maximum pressure is exceeded, the oil being circulated back to the store tank until the relief valve falls again.

The oil inlet pipes cannot be seen on the drawing as they are on the other side of the pump blocks. The pump may be mounted over the store tank, the inlet pipes projecting downwards from the pump blocks. Alternatively the store tank may be mounted a few feet above the pump, giving the additional advantage of a gravity feed.

The pumps may be designed to produce both high and low pressure, or low pressure only. Low pressure pumps may be operated in conjunction with intensifiers for high pressure production.

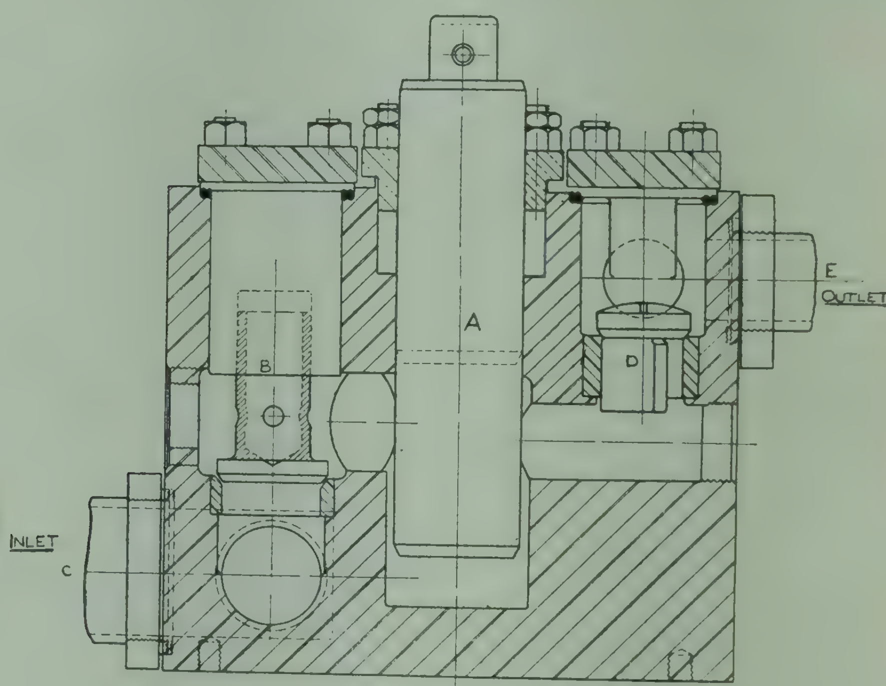


Fig. 11 Hydraulic Pump Block

Pump Body and Valve Box

This single unit for each piston is made of steel as also the valves. Fig 11 shows a sectional view of the box. The piston (A) is shown at the lower limit of its stroke, while the dotted lines show the upper limit. On the commencement of the upward stroke, the pressure drop in the cylinder causes the outlet valve (D) to drop securely on to its seat and seal off any back flow from the system, which is, of course, under pressure at the same time.

At the same time, the gravity feed inlet at (C) lifts the inlet valve (B) from its seat and oil flows into the cylinder. At the top of the stroke, the cylinder is now full of oil about to be pushed out by the down stroke. The increase in pressure caused by the downward stroke of the piston overcomes the pressure

of the flow at inlet (C) and pushes the valve (B) hard on to its seat, thereby sealing off any tendency to leakage back to the store tank.

As soon as the pressure in cylinder exceeds that in the outlet pipe and system, the valve (D) is lifted and oil discharges from the cylinder into the hydraulic system which includes both the press cylinders and accumulators. The action is the same for both high and low pressure.

Capacity of Pump

The pump, as described, is capable of delivering 29 gallons of low pressure oil and four gallons of high pressure oil per minute. The total thrust on the L.P. pistons is approximately 8,800 lb., while that on the H.P. is approximately 8,000 lb. Thus it will be seen that the thrusts are fairly closely related, the actual pressure produced being controlled by the H.P. and L.P. accumulators.

CHAPTER V.

OIL MILL EXPELLERS

This machine is also known as the continuous screw press. In using this name, however, care should be taken to see that it is not confused with the old-fashioned screw press referred to in volume I. The operation of the hydraulic press has been described in previous chapters as well as its ancillary equipment, and the student will no doubt be aware that certain disadvantages are much in evidence:

(1) Heavy labour force per crushing unit.
(2) High cost of press bagging.
(3) Spasmodic operation.
(4) Arduous nature of manual operation.

The screw press suffers from none of these disadvantages, and although there are some undesirable characteristics in the process, it is certain that on balance, the final advantage lies with the expelling process.

There are many designs of expeller on the market and special claims are made for each design, but fundamentally, these machines are fairly similar in their assembly and performance. Expellers tend to fall into two categories: (a) Low pressure and (b) high pressure expellers.

The Low Pressure Expeller

It should be explained here that, owing to the enormous difference in natural characteristics of the various nuts and seeds, it is impossible to lay down a specific procedure for all types. Generally speaking, seeds with a low oil content can be effectively processed in one operation, but with seeds in the

higher oil content groups, two or three operations may be desirable and economical. It is in the double and treble crushing operation that the low pressure expeller is used, and it is always in the preliminary stage or stages.

The following chart shows the three chief processing arrangements involving L.P. expellers. The pre-treatment processes are omitted at this stage, and only the actual oil producing operation is given.

HIGH OIL CONTENT SEEDS

1. Double Expelling	2. Expelling and Hydraulic Pressing	3. Expelling and Extraction
Seed	Seed	Seed
L.P. Expellers	L.P. Expellers	L.P. Expellers
Oil — Cake	Oil — Cake	Oil — Cake
Cake → H.P. Expellers	Cake → Hyd. Presses	Cake → Extractors
Oil — Expelled Cake	Oil — Pressed Cake	Oil — Extracted Meal

It will be seen from the chart that the L.P. expelling process occupies a similar position in all three process sequences.

Students may wonder why two or three stages are necessary and how these can be economical. The explanation lies in the fact that the removal of part of the oil in seed is a comparatively easy process. The difficulty lies in the removal of the maximum possible amount. Accordingly, the final process in each case is the more expensive and should be reserved for a minimum amount of material which justifies its use.

Low Pressure Expeller Assembly

The Expeller has two main parts :

(1) The worm or screw.
(2) The cage.

The *Expeller* worm is composed of 9 steel segments (B) keyed on to the main shaft (C). The first four segments (B) 1, 2, 3 and 4, are housed in the primary and preliminary cages, and the pitch of the screw can be clearly seen to diminish progressively. The main compression segments, 5, 6, 7, 8 and 9, are housed by the main cage and a diminishing pitch is likewise met here as well as an increase in the root diameter of successive segments. Note the sharp leading edge on the helix of each segment. Between each segment in the main compression chamber a distance piece is fitted. The distance pieces are important for two reasons. They link up the changes

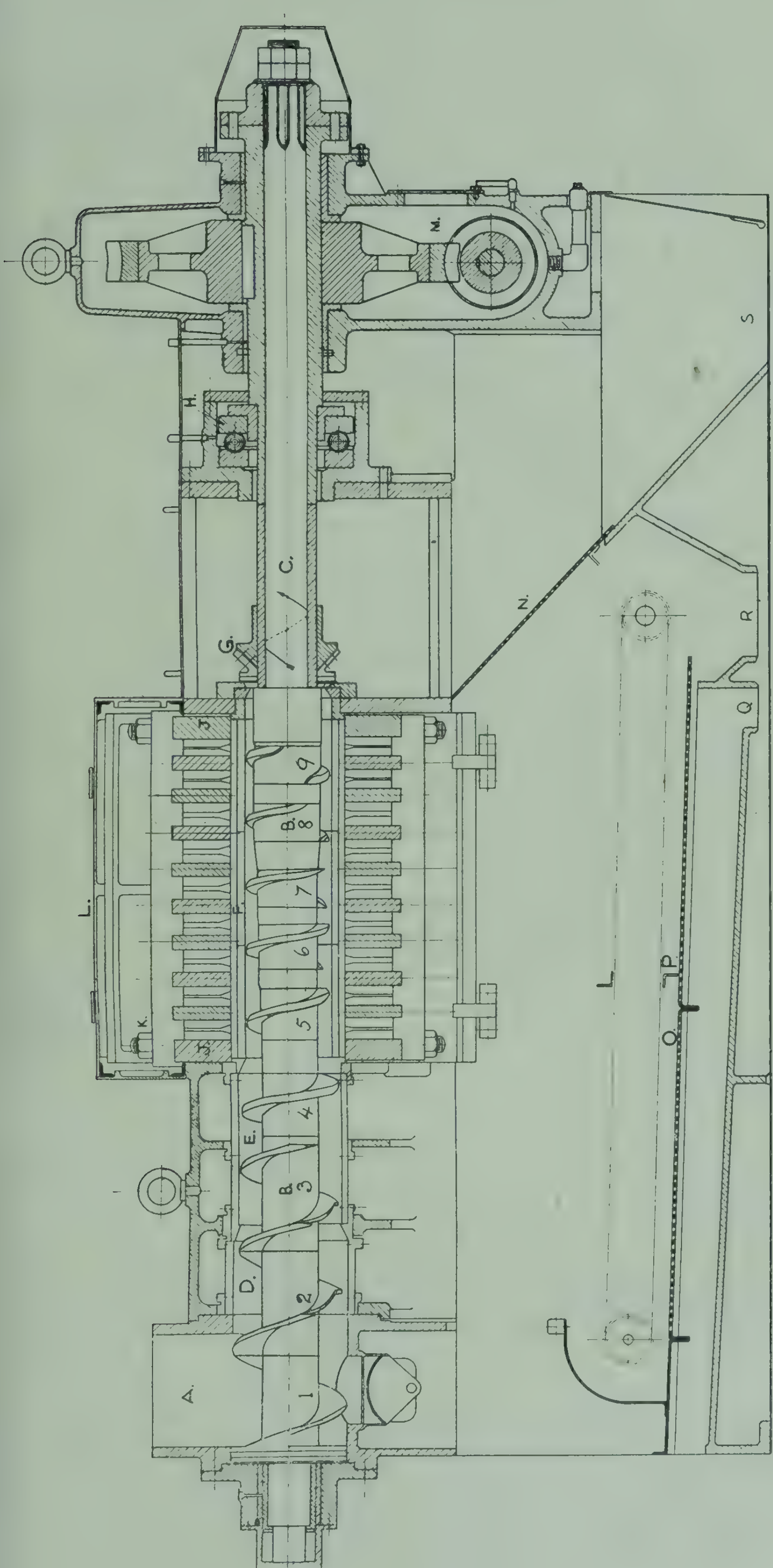


Fig. 12 SECTIONAL VIEW OF L.P. EXPELLER

(A) Feed Inlet, (B) Pressure Worm Segments, (C) Shaft carrying segments, (D) Primary Cage, (E) Preliminary Cage, (F) Main Cage, (G) Cake Breaker, (H) Main Thrust Bearing, (J) Cage Frame, (K) Tension Bolts, (L) Cage Cover, (M) Worm Reducing Gear, (N) Oil Trap (Cake pathway), (O) Extrudings Trap (Oil pathway), (P) Screen Scrapers, (Q) Oil Exit, (R) Extrudings Exit, (S) Cake Exit.

in root diameter and also provide intervals for the provision of cage knives which obtrude into the main compression chamber. The knives in the auxiliary compression chamber are accommodated by means of a gap in the helix and later by the removal of part of the helix.

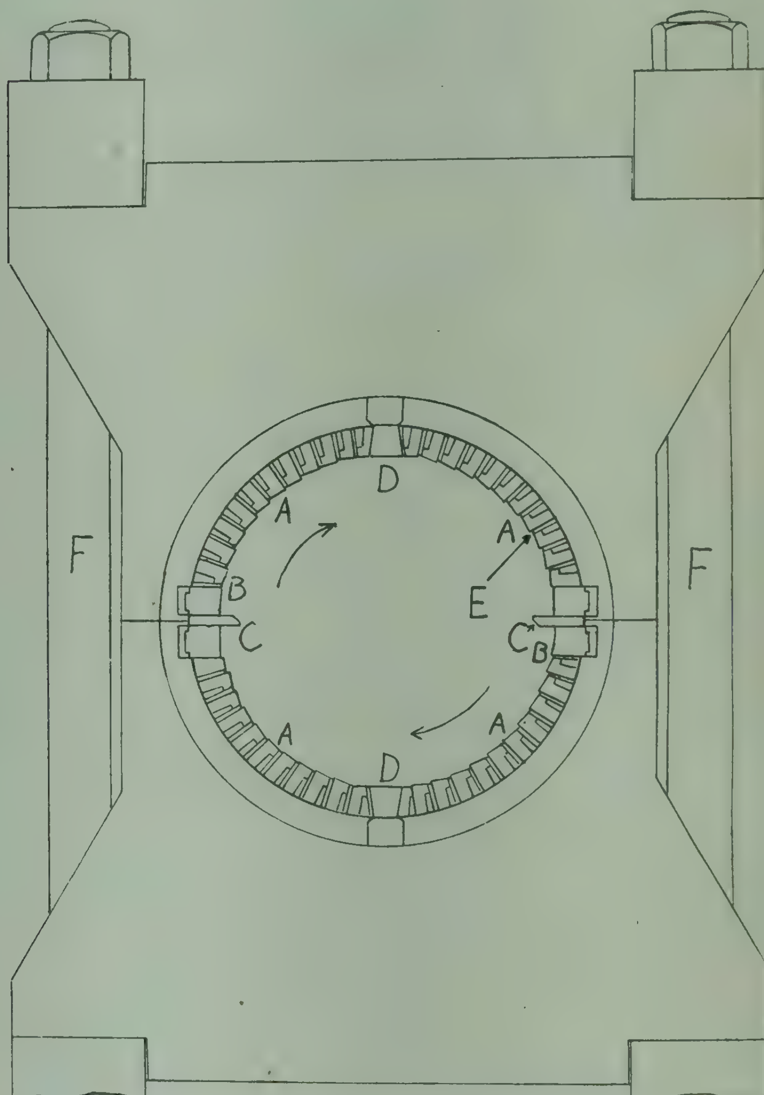


Fig. 13 END ELEVATION MAIN CAGE ASSEMBLY
(A) Cage Bars, (B) Shoe Bars, (C) Knives, (D) Key Bars, (E) Shims, (F) Cage Bolts

Immediately outside of the exit annulus for the expelled cake a breaking device is fitted. This cake breaker is a circle of sharp, steel teeth, which push the cake outwards and tear it into small pieces. The shaft is carried by a strong thrust bearing (H) and is driven via a worm and spur drive (M) by a 40 h.p. motor.

The shaft speed can be varied for different classes of work and is usually between 15 and 40 r.p.m.

Cage Assembly

The cage consists of three separate assemblies, each with a top and bottom half—(D) Primary; (E) preliminary; (F) main (Fig. 12).

Originally, the primary cage chamber (D) was simply used to commence compression, and the housing was a plain tube. The latest machines, however, are equipped to take full advantage of any oil release at the earliest possible point. The cage bars are tightly held on the inside face of two semi-circular steel bars by means of the key and shoe bars (B and D) (Fig. 13).

The slotting of the cage may take one of two forms. The more popular method requires the fitting of shims, or distance pieces, between the cage bars at the points protected by the steel supports. The thickness of the shims determines the width of the slot and these may vary from .04 in. to .06 in.

The other method consists of machining the sides of the bars at intervals to create the slots from the solid. This method is more expensive and is being superseded gradually by the plain bars with shims. A plain steel ring is used to divide the primary from the preliminary cage, and the ring is used to produce a reduction in cage diameter at this point.

The preliminary cage (E) is constructed in a similar manner to the cage (D) and a further step-down in diameter takes place at the point where the main cage (F) is met. It is in the main cage that the most severe compression takes place, and in order to withstand the high pressures set up, the cage is specially constructed.

Main Cage Assembly

The upper and lower halves of the main cage assembly (Fig. 13) are identical, so that the same description will serve for both. Ten forged steel plates with a semi-circular recess cut in the top edge are linked by means of three longitudinal steel ties. The ties also serve as anchors for securing the shoe bars (B) and the key bars (D).

The cage bars (A) are thereby laid on the surface of the recess with appropriate size shims to ensure the necessary gaps or spaces for the passing of the oil. The keybar, as its name infers, is tightened hard down onto its tie when the cage bars are in correct alignment, and its wedge shape ensures that no movement can take place.

When the lower part of the cage has been placed in position on the underside of the worm, the knives (C) are placed in the position shown on diagram (Fig. 13) and the upper half is then let into its appointed place above the lower cage. A pair of stout

steel beams laced with 10 strong tie bolts and nuts are fitted into the shoulder recesses in the plates on each side and the nuts tightened hard. The cage is now a complete and immensely strong unit with a circular bore housing the worm segments.

The diagram shows clearly that the cage bars do not provide a true circle and that each produces a tiny recess where the succeeding bar is met. The recesses tend to facilitate the escape of the freed oil.

The clockwise turn of the worm puts a tension on the cake which discourages it from passing out through the cage bars with the oil. The whole unit is completely enclosed to prevent the escape of vapourized oil to the atmosphere.

A vertical circular sectioned pipe or feed shaft chamber links the cooking kettle with the inlet hopper (A) (Fig. 12), and running through the pipe is a feed shaft fitted with short cross arms at intervals. A controlled orifice at the lowest position on the side of the cooker allows the conditioned seed meal to enter the feed shaft chamber and the cross arms on the feed shaft ensure that a continuous supply of meal shall enter the hopper (A) and into the first compression chamber of the expeller.

Operation of L.P. Expeller

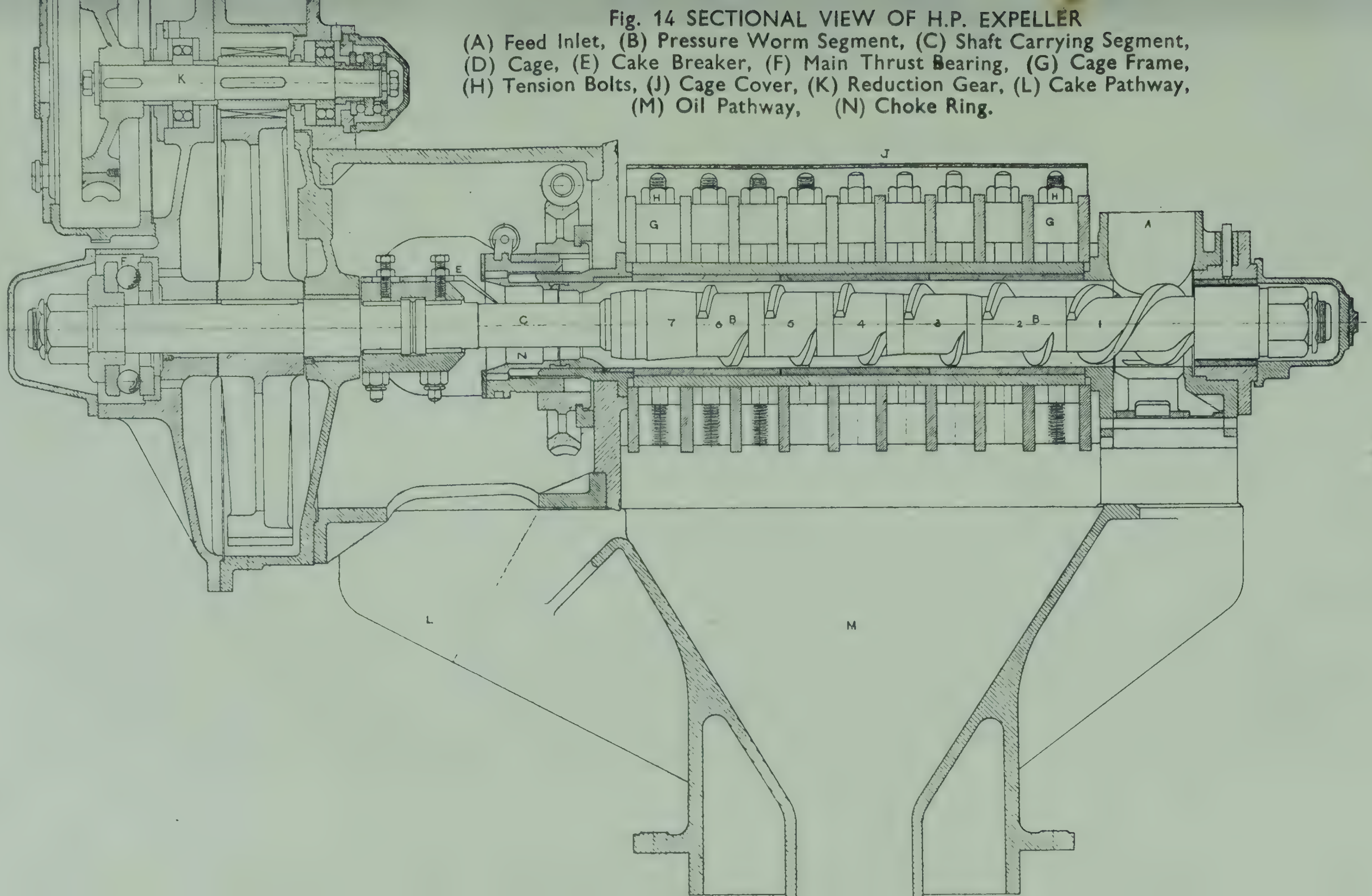
The conditioned meal enters the compression chamber of the low pressure expeller via the inlet (A) and the diminishing pitch of the segment (B2) provides a slight compression. A certain amount of oil which has been partially freed from the cells by the rolling and cooking is pressed out from the meal and escapes through the slots in the cage. The slots at this point, i.e. the primary cage, are as large as possible, since there is little tendency for the meal to be pressed out with the oil.

The meal now enters the preliminary cage chamber where the annular space has been reduced. The reduction of the annular space together with the further diminishing of the pitch intensifies the compression causing more oil to flow from the meal. The meal, now at a reduced oil content, next enters the main cage chamber where the outer diameter of the annulus is further reduced, and after passing the segment (B5), the inner or root diameter increases, causing another reduction in annular space.

On passing each segment, the annular space is progressively reduced and the pressure exerted on the meal is very great. Oil is removed continuously on the journey through the cage chamber, but the high pressure exerted necessitates a reduced size of slotting in main cage as a small quantity of meal now succeeds in forcing its way through the slots with the oil.

The slot sizes may now be reduced to as small a width as $\frac{10}{1000}$ inch, but at this stage in the study of the expeller, an

Fig. 14 SECTIONAL VIEW OF H.P. EXPELLER
(A) Feed Inlet, (B) Pressure Worm Segment, (C) Shaft Carrying Segment, (D) Cage, (E) Cake Breaker, (F) Main Thrust Bearing, (G) Cage Frame, (H) Tension Bolts, (J) Cage Cover, (K) Reduction Gear, (L) Cake Pathway, (M) Oil Pathway, (N) Choke Ring.



exact size cannot be quoted since a specific type of seed has not been dealt with.

During the progress of the meal through the expeller, any tendency to turn with the shaft is prevented by the obtruding knives. A straight through passage of the meal is therefore ensured. The final step-down in the annular space is met at the cage outlet and the resultant cake takes the form of a fairly solid tube. On passing out of the cage, the cake is forced against the teeth of the cake breaker and is broken into pieces of a size convenient for treatment by a gannow. The screen (N) traps any oil which may cling to the cage.

The oil, on leaving the cage, unavoidably contains some particles of the cake meal, and the larger particles should be removed before the filtration operation. The equipment for attaining this pre-filtration separation is shown below the main expeller assembly. The extruded meal particles and oil drop on to a $\frac{1}{8}$ inch screen (O) and the oil and small particles pass through to the filtration tank.

Two angle iron screen scrapers carried on light chains continually sweep or scrape the screen surface and remove the larger meal particles. These particles, or extrudings as they are called, are passed via elevator, reducer and conveyor to the cooker where the fresh seed is met. In this way the extrudings are circulated back for reprocessing. Further treatment of the cake in the case of group 1 on the chart calls for a description of the high pressure expeller which embodies the final oil removal process.

Performance

An expeller of the type described requires about 40 h.p. and will deal with approximately two tons per hour at a speed of from 25 to 35 r.p.m. The oil removed in one expelling process is about half of the total oil content, though this figure is subject to many conditions and types of seed which require further study.

Owing to the need for preserving the structural strength of certain seeds in the initial expelling process, the greatest care is necessary in the pre-processing operation, e.g., groundnuts cannot be subjected to A.A. rolling, moisture application must, in general, be very limited. The over-moistening of seed meal results in slip taking place inside the expeller and this results in loss of compression and failure to remove oil.

The High Pressure Expeller

The previous remarks on low pressure expellers indicated that, for the purpose of removing oil from high oil content seeds, it is held that two or sometimes three stages of expelling are desirable. It is by no means correct to assume this is absolutely essential.

The high pressure expeller is capable of processing many types of high oil content seeds in one stage only. The reasons for not doing this are mainly in the realm of economics. These machines are also used as first stage expellers prior to extraction in certain circumstances. Since three different types of performance can be obtained, the reader will probably realize that slight modifications will be necessary in order to change the role of the high pressure machine. We shall assume that we are dealing with a high pressure expeller equipped for the final expression of oil. The bulk of the oil, therefore, is removed in the early stages by means of the L.P. expeller, and the remaining portion of removable oil is expelled by means of the H.P. expeller.

The material we have chosen for the process is decorticated groundnut with an oil content of 48 per cent. oil and 4.5 per cent. moisture. The analysis after the first expelling will probably be approximately 25 per cent. oil and 7 per cent. moisture. At this point, perhaps a description of the machine is necessary.

H.P. Expeller Assembly

Like the L.P. machine, the H.P. expeller can be divided into two parts, although the driving unit, because of the large step-down in speed, should be included as a third part of the assembly. The design of the segments shows a marked difference from those of the L.P. expeller. The helix diameter is constant throughout.

The first segment (B1) (Fig. 14) is double threaded with a steep or coarse pitch. In the case of the second segment the pitch of the thread diminishes and a distance piece known as a collar connects with the third segment. The diameter of the collar increases to meet the increased root diameter of the third segment and a further diminution of pitch is again noted. The root diameter of succeeding segments continues to increase and the pitch, to further diminish, until the final segment and collar is met. Following the final segment a shallow cone is mounted, and the whole unit is tightened hard against a turned flange by means of the nut on the extreme right.

Cage Assembly

The method of securing the cage bars is similar to that used for the L.P. expeller. The internal diameter is constant throughout. The bars are machined at intervals along one face so that, when the machined face of one bar is placed alongside the plain face of the second bar, the spaces caused by the machining appear as narrow slots. The slot sizes are not constant for the full length of the cage and depend upon the material being processed.

At the feed end of the cage the slots should be approximately 0.7 mm. The middle drops to 0.35 mm., while in the final section of the cage the slots are 0.25 mm. The diminishing size of slots is necessary because the increasing pressure exerted as the cake travels through the machine tends to force the meal out through the slots. The cage knives are held securely in the recess in the upper and lower halves of the cage when the clamping beams and bolts are tightened in position.

At the exit point of the cage a special device is fitted which provides for a variable restriction of the exit orifice. The device takes the form of a tubular wedge or choke which can be moved towards the cone by the machine operator. The lateral movement of the choke is caused by turning a large wheel on the outside of the machine frame. The shaft which carries the wheel also carries a worm linked with a worm wheel. The worm wheel is connected by means of its threaded bore to the carrier of the choke. Machines of this type require a very low turning speed. This is effected by means of the reduction gear (K), the worm being driven by means of a belt from a 10 h.p. motor. The worm wheel shaft carries a small toothed wheel which, meeting with a larger wheel on the stub shaft, effects a further speed reduction.

The main and stub shafts are connected by means of a bolted coupling which also carries the cake breaker (E).

Operation of H.P. Expeller

Material such as palm kernels, groundnuts, cottonseed, linseed and others can be processed with success in a single expelling operation or, alternatively, may be passed through a low pressure expeller beforehand. Should the oil content of the seed be reduced considerably before the final expelling, say to 16 to 20 per cent. oil, the turning speed of the expeller shaft should be about 8 to 10 r.p.m. The resultant cake in this instance will contain between 5 and 7 per cent. oil.

Where the oil content of the cake or seed entering the expeller exceeds 20 per cent., say up to 30 per cent., the tendency will be for the H.P. expeller to leave a larger percentage of oil in the cake. To offset this, the speed of the machine must be reduced to 6 or 7 r.p.m., and for larger amounts of oil in the expelling subject, it may be necessary to reduce the speed to as low as 4 or 5 r.p.m.

The throughput, or work done by the machine, is proportional to its speed; therefore, the higher the r.p.m., the greater the amount of material treated.

Feeding Device

The sectional drawing (Fig. 14) shows the expeller inlet (A), but does not show the feed chamber above. Immediately

above the inlet (A), a vertical tubular feed chamber connects with the side of the cooking kettle. The exit hole from the cooker can be varied or shut off completely by means of a manually operated slide. Running through the length of the feed chamber is a steel feed shaft driven by means of a jockey tensioned belt. The jockey tension allows the belt to slip when the feed into the expeller is too great.

The feed shaft carries prongs at intervals which keep the feed on the move and prevent blocking in feed chamber. At the end of the feed shaft an impeller is fitted, its purpose being gently to impel or guide the feed on to the segment (B1) of the expeller.

Performance

When the machine is about to commence its task, the greatest care is necessary on the part of the operator. The metal of the machine is probably cold, and hasty or careless handling would cause a complete blockage in the cage chamber due to the hardening of the material inside. Therefore, the operator allows only a small feed to enter the expeller by the partial opening of the slide on the cooker wall. The choke on the cage outlet is run out to its maximum open position.

When the metal of the machine has been sufficiently warmed by the meal, the choke is gradually run in until the desired position has been obtained and thereafter, the cooker slide opening is gradually increased until the maximum flow of meal has been obtained.

Inside the Cage

The feed of cooked meal is pressed by the impeller on to the segment (B1) which carries it into the cage chamber. On meeting the segment (B2) the diminished worm pitch tends to hold up the flow of meal. The leading edge of the worm cuts into the layer of meal and forces it forward. Meal is prevented from turning with the shaft by means of the knives along the cage joints. The increasing diameter of the collar forces the meal into a smaller annular space and the pressure on the meal caused by the revolving thread is intensified. The increased pressure causes oil to be pressed out of the meal and force its way out of the cage, via the slots in the cage bars. The meal progresses on its journey through the expelling chamber, and a further gradually diminishing pitch is met, as well as a gradually diminishing annular space. By the time the meal reaches the cone, it has been compressed into a very dense mass, and nearly all of the oil has been squeezed out and forced through the cage bars. On passing the choke (N), the solid mass of cake meets the cake breaker (E) and is broken into conveniently sized pieces for conveyance to the succeeding treatment, i.e., nutting and cooling.

The free oil runs down the pathway (M) to a perforated worm conveyor. Here, any particles of meal which have succeeded in escaping the cage bars with the oil are trapped and conveyed back to the cooker with new meal. The oil passes through the screen to the collecting tank.

ANALYSIS OF MATERIAL TO BE EXPELLED.

The important features which affect the behaviour of materials being expelled are:

(1) Oil content.
(2) Moisture do.
(3) Protein do.
(4) Fibre do.

The oil content of the material for final expelling has naturally been considerably reduced by previous expellings, and in the case of, say, groundnuts, will be about 18 to 20 per cent. The protein content is now a greater part of the total amount by reason of the reduced oil content and so also is the fibre content increased.

It is chiefly on the second feature, moisture, that our interest centres, since this is something which has been definitely affected quantitatively by the cooking process. Dry heat application in the cooking has the effect of driving off some of the natural moisture, whereas live steam tends to increase the moisture content. Excessive moisture results in a soft and pliable expelling subject which, instead of standing up to a pressure inside the expeller, would merely slip and slide

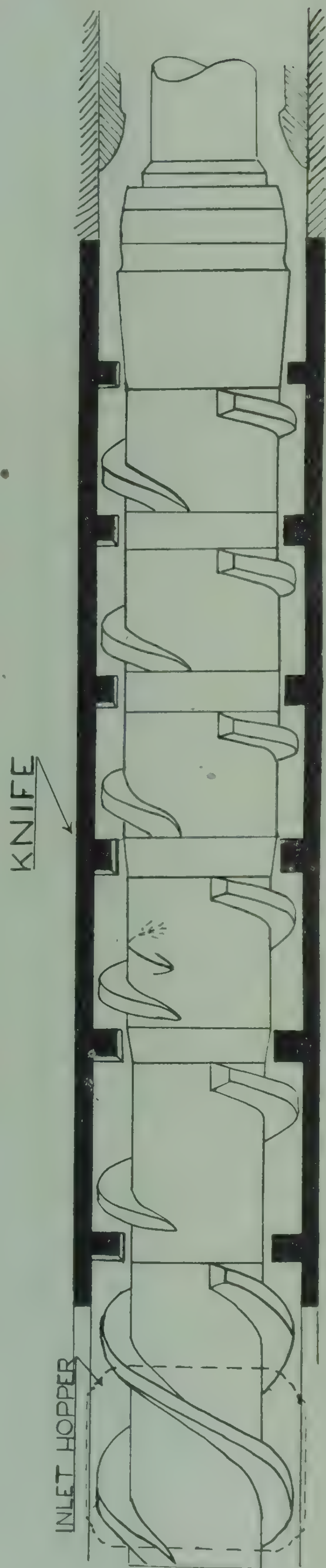


Fig. 15 Plan view of H.P. Expeller Worm showing Knives in position.

through without giving up oil. It is essential, therefore, that the moisture content be kept at a minimum, and that jacket heat only be applied in the final stage of cooking. The resultant moisture in finished cake is always low and represents a definite processing loss.

Capacity of Expeller

The capacity of an expeller cannot be stated without qualification. Should the objective of the process be the largest possible throughput of raw material, this can be obtained by running the machines at high speed. This would result in reducing the work done per unit quantity of material, resulting in a high percentage residual oil.

The seed crusher is anxious to retain a constant oil content in his finished product, and to obtain this for the various combinations of process, the speed at throughputs stated on the following charts may be taken as reasonably correct.

SINGLE H.P. EXPELLING

100 Tons Groundnuts at 48 % Oil

H.P. Expeller at 4 r.p.m.

Oil 44.1 Tons or 44.1 % removed	Cake at 7 % Oil 55.9 Tons

Six High Pressure Expellers working for one week of 120 hours would be needed to produce the above amounts. The hourly throughput per machine, therefore, is slightly more than 3 cwt.

DOUBLE EXPELLING USING ONE L.P. AND 6 H.P. EXPELLERS

100 Tons Nuts
at 48 % Oil

L.P. Expeller
at 21 r.p.m.

Oil 30.7 Tons	Cake at 25 % Oil—69.3 Tons

H.P. Expellers
at 6 r.p.m.

Oil 13.4 Tons 44.1 Tons—or 44.1 % Oil removed	Cake at 7 % Oil 55.9 Tons

The above processing would take approximately 50 hours or at 120 hour week the throughput would be 240 tons.

It will be seen from a comparison of the above processes that double expelling has a definite advantage over single expelling.

The accompanying view of H.P. Expeller worm shows the knives as they would appear when the top part of the cage is removed. The front and outer edges of the blades are chamfered to facilitate the forward flow of the cake. The chamfer occurs

on the side of the knife opposite the direction of rotation and can therefore be seen on one knife only. This disposes the maximum knife surface to oppose rotary motion on the part of the cake.

CHAPTER VI.

FILTRATION

So far, we have come to the point where oil seeds have been separated into the two commodities which the whole of the previous processing was designed to effect, namely :

(a) Oil.
(b) Cake.

From this point, the oil and cake travel entirely different paths, and are subjected to widely differing treatment. Eventually, the oil passes into the sphere of the refiner, while the cake finishes up in the compound feeding stuffs factory. Both of these are separate spheres of influence from each other and from the seed crusher. However, there are still certain operations which must be carried out before the two commodities leave the seed crushing mill.

The present chapter seeks to deal with the oil. When oil is expressed or expelled from oil seeds, a certain quantity of small particles of meal inevitably passes with the oil to the collecting tank. Some of the coarser meal is removed by screening, or alternatively by centrifuge, but no screen will effectively remove all of the meal.

The original method of removing solid particles of meal consisted of allowing the oil to settle for a long period. The solid matter, and possibly mucilage suspended in the oil, slowly dropped to the bottom of the tank and the clear oil was drawn off from a point above the settlings, or foots, as they are more commonly called.

It is more usual nowadays to remove the foots by filtration. This method does not require prolonged storage of the oil, indeed, best results are obtained when the oil is treated while still hot from the presses.

The Oil Filter Press, Plate and Frame Type

The principle consists of forcing oil through a layer of cloth and trapping the solid matter on the outer surface. There are many designs of filter press, most of them essentially similar in principle. They differ chiefly in size and in the method of opening and shutting, also in the mounting of the cloths. The aim of the designer is to present the maximum cloth surface to the oil.

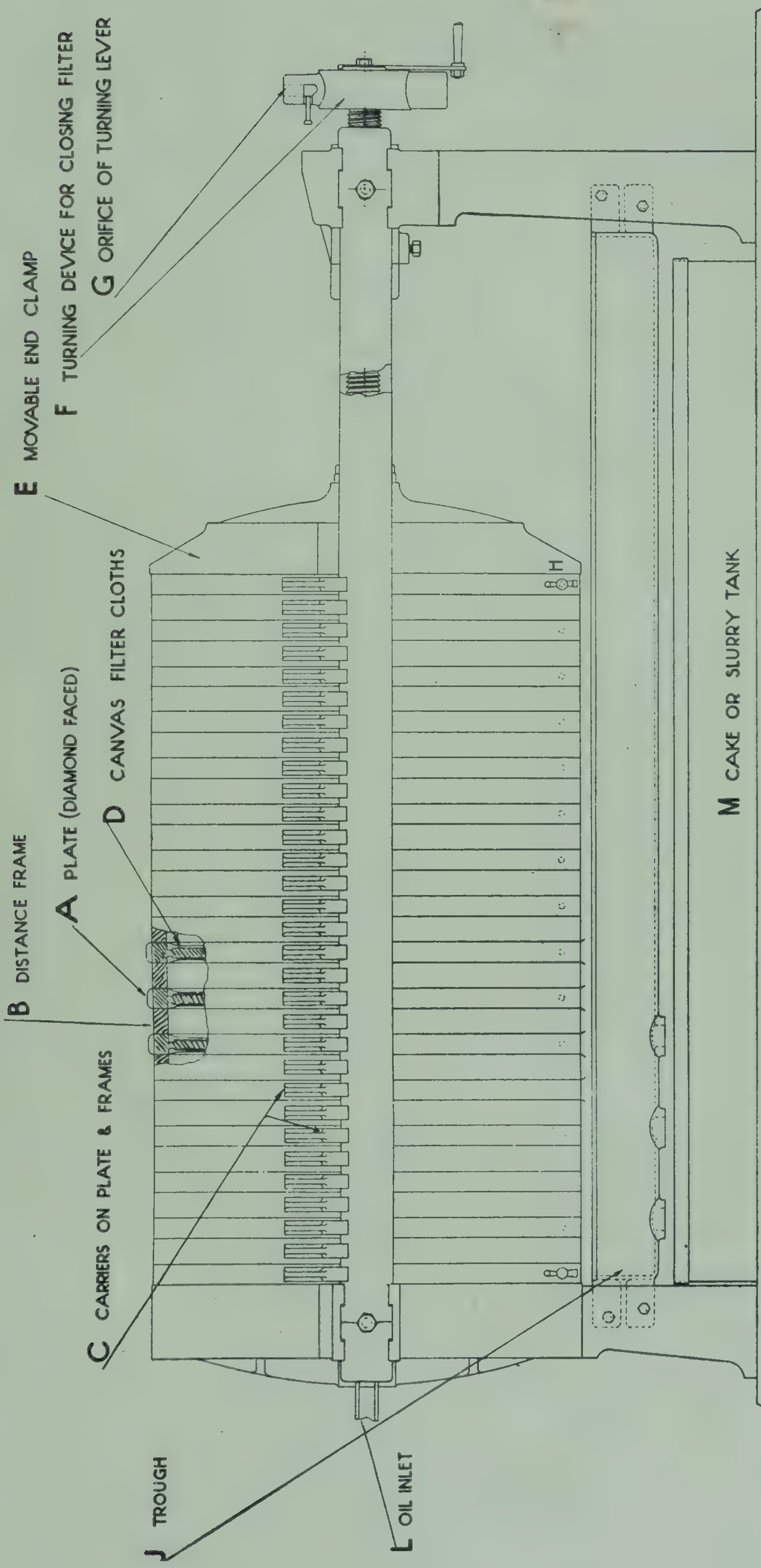


Fig. 16 OIL FILTER PRESS

Description of Machine

Fig. 16 is a side elevation of a typical filter, as used in the seed crushing industry.

The components consist of two stout end castings of steel or iron, rigidly connected by two forged steel bars. A series of cast steel plates and open frames are mounted alternately by means of the carriers (C) which are a part of each plate and frame. The frames are often made of wood, preferably teak.

The working surface of the plates is deeply inset and the surface is corrugated, diced or ribbed. The grooving can be clearly seen in the part section of the plate (A). The outer or peripheral " land " of the plate is machined to a perfectly true face for effective sealing. Each plate has a fairly large hole surrounded by a machined surface at some specific place on the surface. The more usual place is the centre of the plate.

The hole serves two purposes. The first purpose is the passing of the crude oil through the whole unit and, secondly, the securing of the cloths. The filter cloths (D) are made of strong cotton twill, tightly woven, and are draped over the top of the plate so as to hang downwards on either side. Holes are cut in the cloths at points opposite to the holes in the plates. A flanged coupling piece is passed through the set of holes on each side and one of the coupling pieces screwed into the other.

At the base of the grooved faces, a small slot is joined to an orifice on the side of the plate near the bottom, and into the orifice a tap (H) is fitted. The design of the frames (B) is more simple. A plain frame of wood is reinforced with mild steel rods at the top, bottom and near central points. The carriers (C) are screwed or bolted to the sides. The trough (J) is bolted to the end castings and is situated immediately under the taps for the collection of the filtered oil.

A valve is fitted on each of the three exit orifices shown on the trough (J). The opening or shutting of the valves enables the operator to send the filtered oil to three alternative points of storage or cooling.

The closing device is, in reality, a huge clamp. The movable end plate (E) is fitted by means of a loose joint to a horizontal shaft threaded in the right hand end casting. The turning device (F) on the end of the shaft is turned by hand in the first instance, and subsequently by means of a tommy bar or turning lever for greater purchase. The bar fits in the orifice (G) and is secured during the operation by means of a spring pin.

Operation of Press

The filter is closed by turning the closing device until all faces of the plates and frames are pressed so tightly together that they are leak proof. The crude oil is now pumped into the filter via the inlet pipe (L) filling the lower part of the space formed by

the first frame via the hole in the first plate. The succeeding flow passes through the holes of the succeeding plates and all frames are soon filled with oil. The pump exerts a pressure sufficient to force the oil through the cloths. The solid matter is trapped on the outer surface of the cloth while the filtered or clear oil flows via the corrugations or channels to the bottom of the plate.

At the plate bottom the oil is forced by the pressure on the cloths to pass via the slot and is ejected by the tap into the trough. Meanwhile, more oil is still being forced into the frame spaces, through the cloths, leaving an increasing layer of meal on the cloth face. As the depth of the meal on cloth surface increases, the oil now has a two-fold obstacle to negotiate. In addition to passing through the cloth, the oil has to pass through the meal. The pump will continue to force oil through the meal and cloths until the maximum pumping pressure is reached. The maximum pumping pressure may vary between 20 and 30 lb. per sq. in.

By this time, the frames have become packed with a mealy deposit called filter cake, and the oil flow from the taps is now so poor that the filter is no longer efficient. To remedy this, the filter must be opened and cleaned. The pump is therefore stopped and the oil trough covered by a lid or protecting sheet of metal. The tension screw is then slowly turned off until the end clamp is free of the last plate. The end clamp is then run back to its furthest position and the first plate is pulled back against the end plate. Some of the deposited cake will fall from the cloth face and the remaining cake must be removed by scraping with a large blunt edge knife or spatula.

The face of each cloth is cleaned in turn and the cake is dropped into a large receiving trough under the machine. When all the plates have been cleaned, the free space is between the left hand casting and last plate, since the plate, after being cleaned, is pushed to the right.

Before commencing the filtration process again, the plates and frames must be pulled back, one at a time, to the original positions and the movable end clamp again screwed hard against the first plate. From this point, the operation originally described is repeated.

The cake trough (M) shown in the illustration now holds a considerable quantity of oily meal or filter cake, and this is removed by means of a spade into a container. To save the labour of spading, most up-to-date filter cake troughs are fitted with a worm conveyor by means of which the cake is passed into the fresh material supply to the cooker for reprocessing.

Capacity of Filter

The capacity of a filter is the amount of oil which can be treated in unit period. This may be expressed in tons per hour

or tons per cycle. The period of the cycle should, of course, be stated, and refers to the period over which the filter will function between cleaning operations and including one cleaning period. The capacity is proportional to the total area of the cloth working surface. A typical filter of a type somewhat larger than that shown in the illustration is equipped with 31 plates, each of which has two filtering areas 39 in. × 39 in.

$$\text{Total filtering surface, therefore,} = \frac{2 \times 39 \times 39 \times 31}{144}$$
$$= 655 \text{ sq. ft.}$$

The cycle period must, of course, vary according to the type of oil under treatment, its percentage of solid matter and the particle size of the solid, plus the nature of the solids. The percentage of moisture present also influences filtration.

The average throughput of the above filter is approximately three tons per hour. It must be pointed out, however, that this throughput speed includes the cleaning period when no oil is flowing. When the filter has just commenced work, the rate of filtration is very high indeed, but the rate drops rapidly as the filter chambers become packed with residual cake. The maximum recorded throughput for the first two minutes work may be as high a rate as 20 tons per hour. It is difficult to state just how many tons of crude oil can be treated for each filter run or cycle. Although this amount is determined partly by the details stated above, it is also dependent upon the volume available for the separated meal. The press described has a frame size 39 × 39 inches inside dimensions at a thickness of $1\frac{1}{2}$ inches. The volume available to the trapped meal, therefore, equals 39 in. × 39 in. × $1\frac{1}{2}$ in. per frame.

$$\text{The total frame space} = \frac{39 \times 39 \times 1\frac{1}{2} \times 30}{1{,}728}$$
$$= 39 \text{ cu. ft.}$$

1 cu./ft. of foots will weigh approximately 56 lb. The total amount of foots, therefore, which can be separated by one cycle of the filter is

$$\frac{39 \times 56}{112} = 19\tfrac{1}{2} \text{ cwts.}$$

Should the foots be 5 per cent. of the crude oil, the total amount which can be treated

$$= \frac{19.5 \times 100}{5} = 39 \text{ tons}$$

In the case of cottonseed oil, the foots are usually of a very coarse nature due to the presence of husk, and oil can pass through the foots until the whole filter is tightly packed with meal. Where the protein content of the raw material is high, as in the case of decorticated groundnuts, the fineness of the texture results in a thin impervious deposit on the cloths, and the filter ceases to pass oil while the frame spaces are by no means filled.

The fine meal is almost pure protein, and the remedy for this condition lies in preventing the fine meal from leaving the expeller or hydraulic press. Live steam applied near the end of the cooking process will often accomplish this and the rapid coagulation of the protein which results will tend to bind the

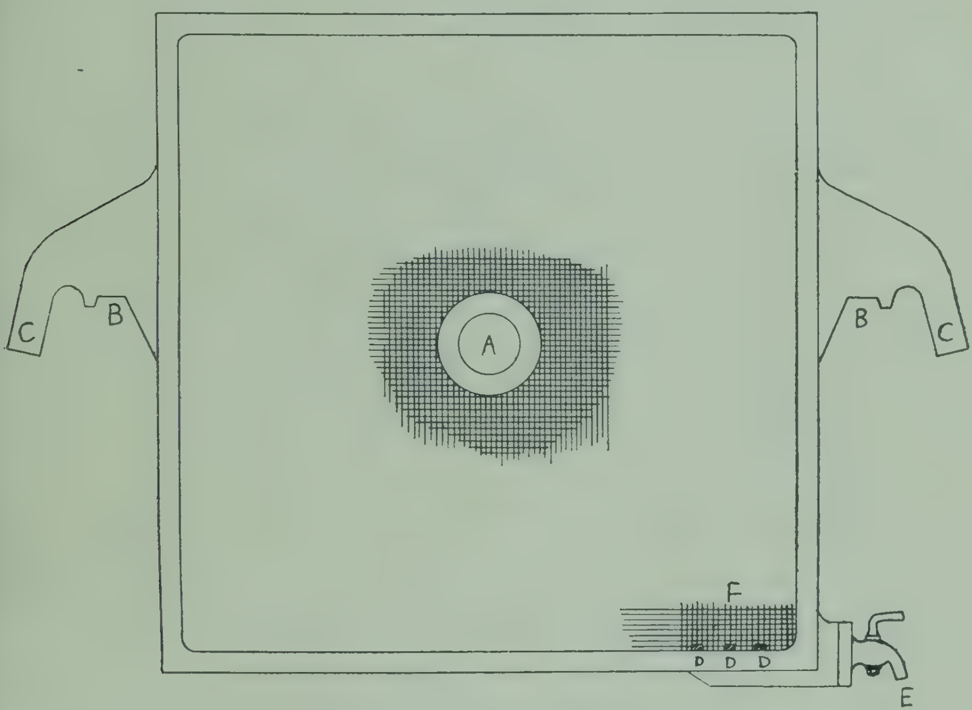


Fig. 17 **Standard Filter Plate**

meal particles closer together, thereby preventing them from flowing away with the freed oil.

Fig. 17 shows a standard filter plate of the type used in the seed crushing factory.

The hole in the centre (A) forms a passage for the crude oil, and also carries the couplings which secure the cloths. The flat surfaces (B) rest on the forged steel bars of the filter frame. The handle (C) enables the plate to be moved forward by hand. The slots (D) drain the filtered oil from the studded surface (F) on the inside of the cloth, and an exit hole is connected to the tap (E).

Life of Filter Cloths

Filter cloths cannot be worked indefinitely without treatment. The finer particles of meal tend to become deeply embedded in the texture of the cloth and the filter knife cannot always dislodge them.

When this condition becomes chronic, the throughput of oil is reduced to such an extent that the cloth must be removed and new cloths fitted. The old cloths can be made usable once more by thoroughly washing them in a caustic solution. The oil in the cloth is saponified and the meal is washed clear. Alternatively, the cloths may be treated in a small solvent extraction plant, in which case the oil is recovered.

When cloths are water washed, a certain amount of shrinkage takes place and allowance must be made for shrinkage when the cloths are being cut. In the first wash, about 2½ per cent. shrinkage takes place, but in subsequent washings this figure is considerably reduced. The advantage of water washing, however, is that the weave of the cloth is tightened somewhat and the likelihood of meal particles passing through with the oil is reduced.

Filter Pumps

It has been stated that the rate flow of oil through a filter is not constant. At the commencement of the filtering operation, the flow of oil is very high indeed. This is because the resistance to the flow is very slight. The only resistance met is that imposed by pipe friction and this is not very large in most cases, as the length of piping between pump and filter is usually only a few feet.

When the spaces of the filter frames have been filled to their maximum and the oil commences to pass through the texture of the cloth, the natural viscosity of the oil combined with the smallness of the spaces between the cloth fibres is sufficient to prevent the oil from flowing freely. In other words, the cloth resists the passage of the oil and this resistance is passed back to the pump. The flow of oil, therefore, is slowed down and the pressure set up by the cloth resistance can be noted on the gauge fixed near the pump orifice. As meal builds up on the cloth face, the resistance is further increased by the fineness of the meal texture through which the oil must pass before reaching the filter cloth.

When the filter spaces or chambers are thoroughly packed with meal, the condition arises when oil ceases to flow entirely although the pump is still working at its correct speed. When this condition operates, the impeller of the pump is merely turning in an oil bath. This means that slip is taking place between the impeller and the oil in the pump chamber. A certain amount

of slip is always taking place, however small is the resistance, and the greater the resistance the greater the slip.

The pump works best with a "head" on the inlet. This ensures the flooding of the periphery and provides an added inducement to the oil to flow with the impeller vanes. The pump used is known as the centrifugal type.

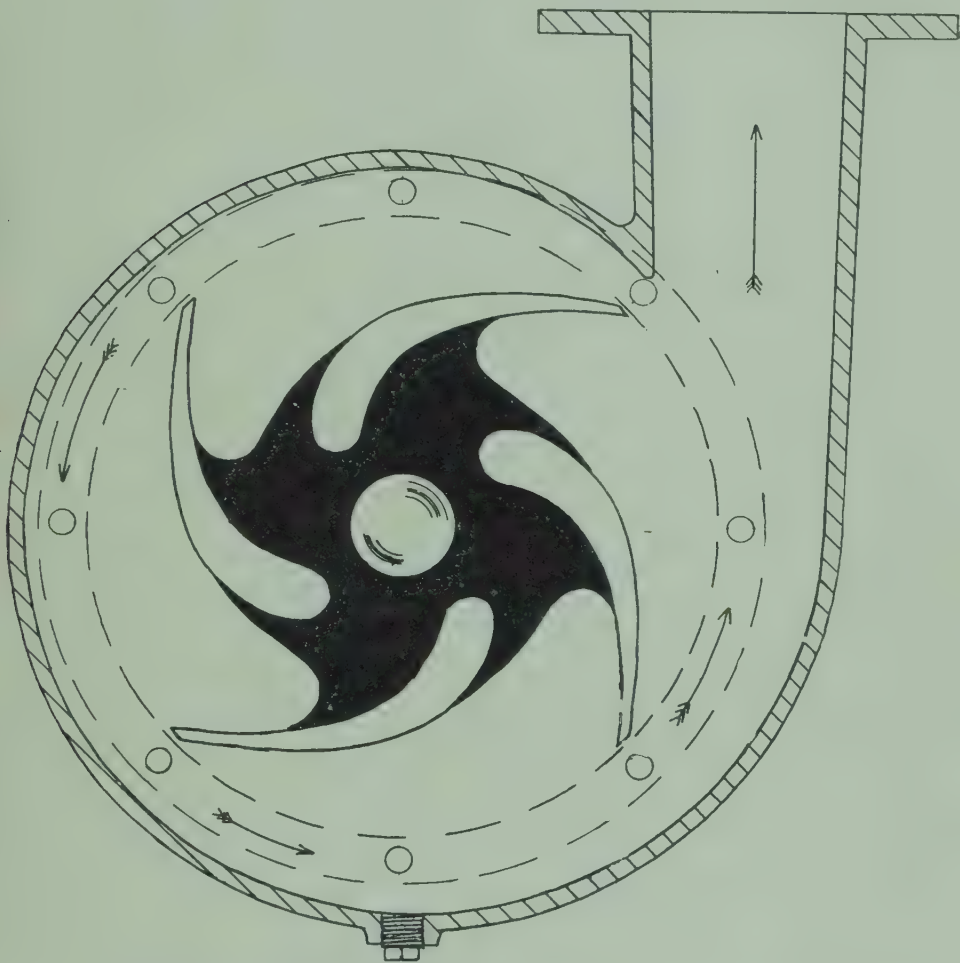


Fig. 18 Centrifugal Pump. Impeller mounted in volute casing showing backward sweep of impeller vanes.

Centrifugal Pump (Fig. 18.)

The pump consists of two main parts:

(a) The Impeller.

(b) Volute casing.

(a) The impeller is a rotating carrier plate on which four vanes are mounted. The shape of the carrier plate is cut in such a way as to afford the maximum strength of the vanes and at the same time to cause the minimum obstruction to the oil flow.

The vanes start at a point near the centre of the impeller and curve outwards and backward. The ends of vanes are deepest nearer the centre and the depth diminishes as they approach the outer periphery of the travel. The depth at the centre affords the optimum volume for the inflowing oil which enters at a comparatively slow speed from a large inlet in the centre of the pump.

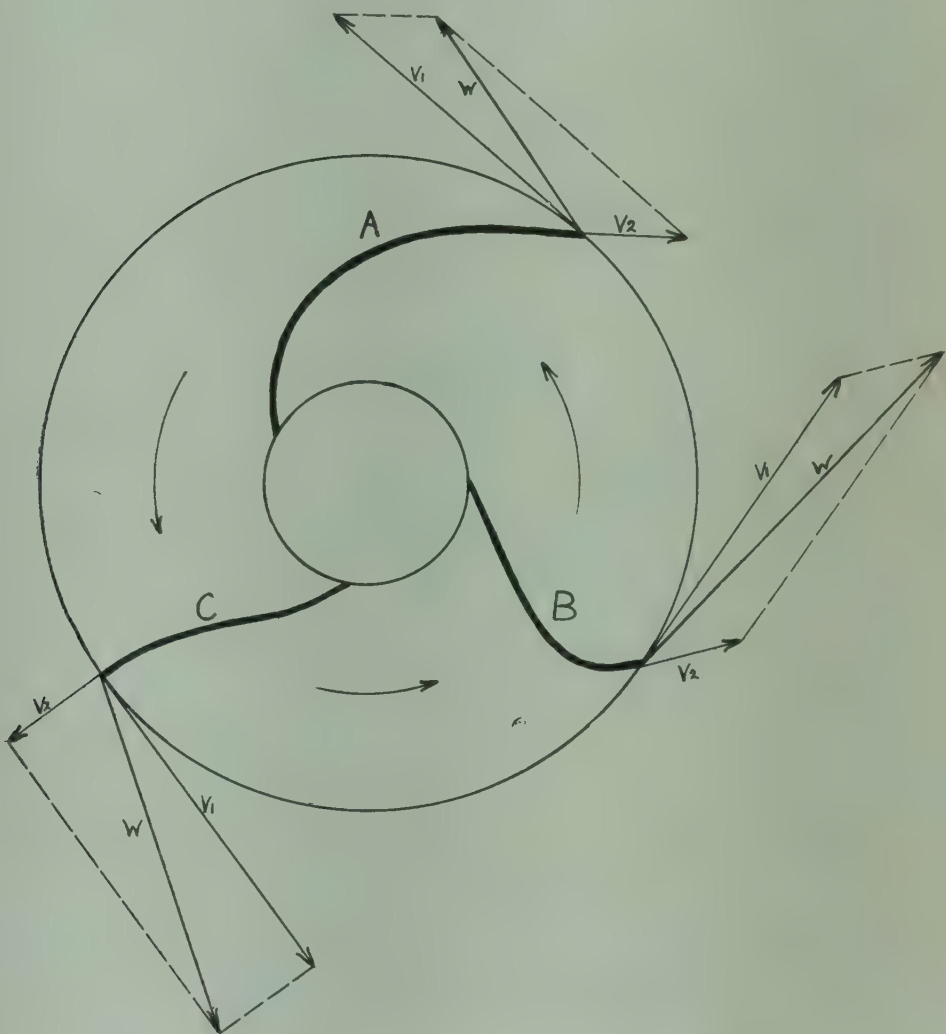


Fig. 19. Three Types of impeller vane showing resultant vectors for each type of vane.

(b) The volute casing is so named because of its tendency to describe a spiral shape. The distance of the outer casing from the impeller centre is smallest at the point immediately behind the exit pipe. This distance increases gradually until the maximum distance occurs immediately before the outlet. The increasing volume of the diffuser or volute space in the casing has

the effect of changing velocity head into pressure head and ensures as constant a rate of flow as possible.

PERFORMANCE OF PUMP.

The fundamental difference between the positive displacement pump and the centrifugal type is that the former generates pressure by direct compression of the liquid, the resulting pressure being the same irrespective of the density, while the centrifugal type, being a velocity machine, imparts energy to the fluid which maintains a column of that fluid at a certain level above the point of application which is stated in " feet head." For this reason, it is usual to refer to head of liquid instead of pressure per square inch, when dealing with centrifugal pumps.

The pump effect is derived from the conversion of velocity energy into pressure energy according to the Torricellian Law: $V^2 = 2gh$.

The pumping medium, in this case oil, is let into the pump at the centre of the impeller where it is picked up by the vanes. The rotation produces centrifugal force and, since the fluid is free to move outward between the vanes of the impeller, it does so and is thrown from the periphery with considerable velocity. The pump casing being initially full of oil, movement is induced by the fresh oil being forced outward and round with the impeller. For this reason, the pump only works effectively when the casing is already full. The performance of the pump is dependent upon the design of the impeller vanes. The impeller shapes will fall into one of the following groups: (a) Backward; (b) Forward; (c) Radial (Fig. 19).

The velocities for each are different; the effect of the shape is shown in the diagram. The direction and shape of the arrow V1 represents the velocity at the tip of the impeller, while V2 represents the speed of the fluid through the impeller. The direction V1 is tangential to the radius, while V2 is in the direction of the impeller vane. The vector produced indicates the resultant velocity of the fluid. Most types of centrifugal pump are fitted with backward vanes as shown at (A), as these vanes give the smallest velocity (W), thereby aiding the conversion to pressure.

Reference has been made to the formula $V^2 = 2gh$ or

$$V = \sqrt{2gh} \quad \text{where } V = \text{velocity at impeller tip}$$
$$h = \text{feet head}$$
$$\text{and } g = 32.2 \text{ or gravitational force.}$$

Thus " head " produced is a function of the square of the velocity at the impeller periphery.

The "head" therefore $= \dfrac{V^2}{2g} = h.$

A pump of the size used for filtration on the scale described would have the following details :

Diameter of Impeller 12 inches.
Speed of Impeller 1,500 r.p.m.

The peripheral speed of the Impeller therefore =

$$1{,}500\ \pi D = \frac{1{,}500 \times 22 \times 1}{7} = 4{,}714 \text{ ft. per min., or } 78.6 \text{ ft. per second.}$$

$$\text{Using } h = \frac{V^2}{2g} = \frac{78.6^2}{2 \times 32.2} = 94 \text{ ft. "head."}$$

This means that the pump is capable of supporting a column of water or oil, or any other suitable liquid, to a height of 94 ft.

The theoretical pressure gauge reading for a "head" of 94 ft. = 36.6 lb. per sq. in. This figure is obtained by taking the atmospheric pressure, divided by the column of water which will support this, multiplied by the "head" of the pump, and multiplied by the S.G. of the pumping medium, i.e., oil at 0.9

$$= \frac{14.7}{33.9} \times 94 \times \frac{9}{10} = 36.6 \text{ lb. per sq. in.}$$

The actual gauge reading will be a little less than this, say, 32 lb. per sq. in. due to minor inefficiencies of pump performance and pipe friction.

CHAPTER VII.
OIL COOLERS

Freshly expelled or expressed oil retains a considerable amount of heat, even after filtration. A certain period of storage is usually unavoidable, and since the oil at this stage contains a certain percentage of free fatty acids, there is a tendency for deterioration to take place. The deterioration tends to be accelerated by high temperature, and for this reason the oil must be cooled as soon as possible.

The most popular cooling medium is water. There are various types of coolers in use and two of these will be described :

(1) Astra.
(2) Gorton.

The Astra type cooler is more commonly used for the cooling of milk and is made in many sizes. The larger sizes only are used in the vegetable oil mills.

The Astra Cooler

A series of 26 horizontal copper tubes of 2 inches diameter are mounted vertically and connected with each other on the outer face by means of $\frac{1}{4}$ inch metal strips. The ends of the tubes are enclosed on either side by vertical connecting chambers which are sealed at alternate points in the vertical rise. The outer surface of the tubing is tinned, this reducing the probability of chemical action between the free fatty acid in the oil and the copper surface.

Water enters the lowest tube with a pressure head of, say, 10 lb. At the other end of the tube the vertical unit provides a common chamber with the tube immediately above, and this

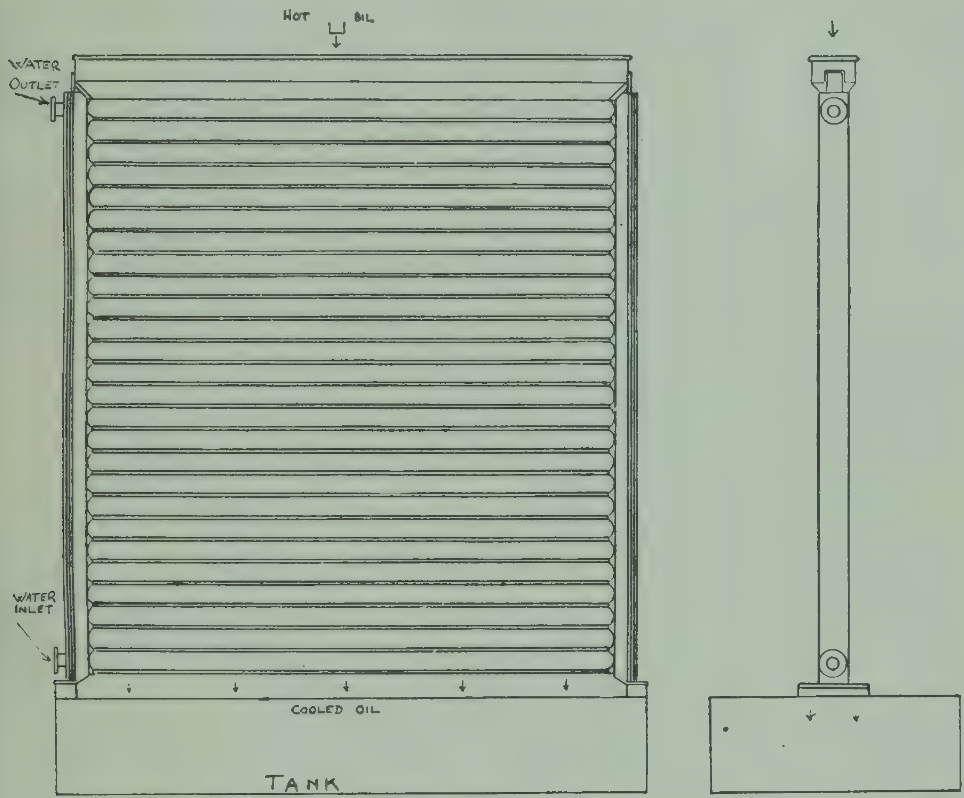


Fig. 20 The Astra Cooler (left) Front view (right) Side view

flows through until the left hand vertical unit is met. Here, another common chamber provides access to the third tube and the flow continues in a like manner until the topmost tube is reached. The top tube is connected with an exhaust pipe and the water, now warmed, is allowed to flow to waste or to a collecting tank for other purposes. The oil is piped to a channel surmounting the cooling tubes.

Near the base of the channel, a series of $\frac{1}{8}$ inch diameter holes are bored in two lanes about $\frac{1}{2}$ inch apart. The holes are at intervals of $1\frac{1}{8}$ inch. As the trough fills, the oil flows through the holes and over the front and back cooling surfaces into a collecting tank, from where it flows to a store tank.

The foregoing indicates that the oil and water flow is in opposite directions, i.e., the water flows from the bottom via the tubes progressively to the top, while the oil flows by gravitation from the top to the bottom. The fresh oil, therefore, meets the warmed, or for our purposes, spent water. The warmed water is still much cooler than the hot oil, and heat is transferred through the copper surface of the tubes to the water.

As the oil flows over the surface of the tubes, its temperature is gradually reduced, but the temperature of the water in the succeeding tubes is also progressively lower. It follows that near the end of the cooler flow, the part cooled oil is in contact with the tube surface housing the very cold water from the inlet point and that a rapid final heat transfer is thereby assured.

Performance

In attempting to describe the work done by the cooler, it is necessary to use a specific case. It will be obvious to the reader that different conditions, temperatures of oil and water and rates of throughput will influence the results obtained.

The following practical test is typical of the cooler's performance:

Oil, groundnut at 158 degs. F.
Water, 54 degs. F.

RESULTS OBTAINED.

Oil Flow per hour (lb.)	Temp. Hot Oil.	Temp. Cooled Oil.	Water Flow per hour (lb.)	Temp. Cold Water.	Temp. Warm Water.
6,720	158° F.	106° F.	6,552	54° F.	78° F.

The table shows that heat has been given up by the oil and that heat has been absorbed by the water. The heat given up by the oil should be equal to that gained by the water.

The equation may be stated thus:

$$\begin{aligned}\text{Heat given up by oil} &= \text{heat gained by water}\\ &= \text{M.} \times \text{SP. HT.} \times \text{T}^\circ\text{ rise}\\ &= 6{,}720 \times 0.45 \times (158-106)\\ &= 157{,}248 \text{ B.T.U.}\\ \text{Heat gained by water} &= \text{M.} \times \text{SP. HT.} \times \text{T}^\circ\text{ drop}\\ &= 6{,}552 \times 1 \times (78-54)\\ &= 157{,}248 \text{ B.T.U.}\end{aligned}$$

Should a lower temperature be required in the cooled oil, the rate of flow of oil over the cooler should be reduced. This has the effect of increasing the amount of water used per lb. of oil cooled.

The Gorton Cooler

Continuing the discussion on coolers, the Gorton type of cooler is totally enclosed and is made in many sizes. The

particular size here described is known as the standard Gorton 180 and is in use in the oil milling and seed crushing industry. The main carcase, or body (A), is of cast or fabricated steel. An upper and lower pass of 82 copper tubes each provide the water passage. The tubes are expanded into the fixed tube plate (E) and the floating tube plate (F). The working length of the tubes is 5 ft. and the total external area provided by the tubes is 108 sq. ft. This constitutes the total cooling area or heat transfer surface.

The tube plate, or header (E), is fixed in position while the tube plate, or floating header (F), is perfectly jointed yet free to move axially when the rise in temperature expands the tubes. Water at 10 lb. per square inch pressure enters via the inlet (N) and flows through the lower pass of tubes reaching the connecting chamber (Q). From the chamber (Q), the water flows through the upper pass tubes and out, via the exit orifice (C).

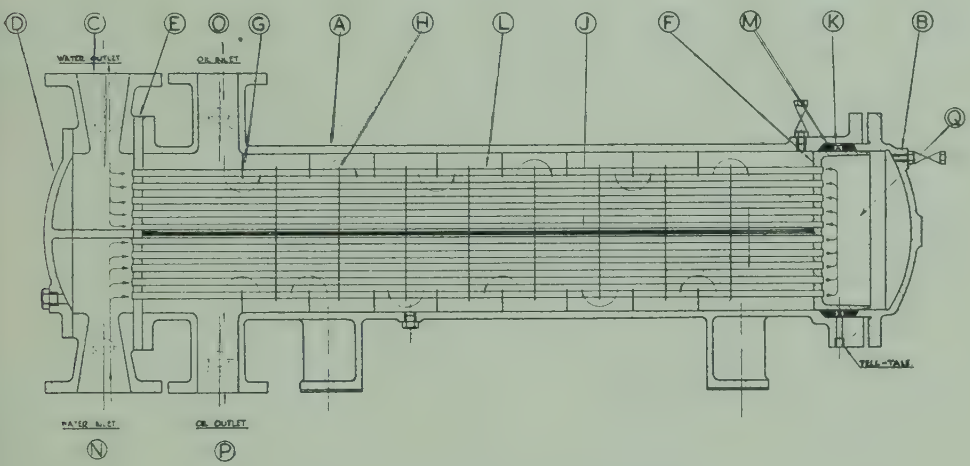


Fig. 21 Gorton No. 180 Cooler

The hot oil enters the upper pass chamber, via the inlet (O) and commences to negotiate the specially designed maze. The maze is produced by the ring and disc baffles (G) and (H) placed alternately through the housing. The flow direction is indicated by the series of curved arrows. At the end of the upper pass chamber, an opening in the centre baffle (J) allows the oil to flow into the lower pass chamber and thence via the second maze out at the orifice (P).

The oil flow direction described provides the maximum opportunity for heat transfer. The oil should flow at a slightly higher pressure than the water so that in the event of leakage at the tubes, oil will pass into the water and not water into the oil.

The special packing (M) between the floating header and the body is made of graphited asbestos and when tensioned by drawing in the body cover (B), forms the best possible seal against leakage.

Should oil tend to leak via the floating header, however, it will find its way out via the steel tube at the bottom and give due warning of a fault. This cooler is capable of handling 6 tons of vegetable oil per hour at a temperature of 130 degs. F. and cooling it to 75 degs. F.

The Gorton cooler is particularly adapted where compactness is required and where space is limited. Moreover, where a large quantity of oil must be cooled rapidly and the maximum dispersion of heat is required, this cooler is advantageous. To achieve the maximum dispersion of heat, it is desirable to use a large volume of cooling water and that, though its temperature will, of course, rise, does not reach the temperature of the oil being cooled.

As the temperature of the cooling water approaches that of the oil, the heat transfer rate slows down. The best heat

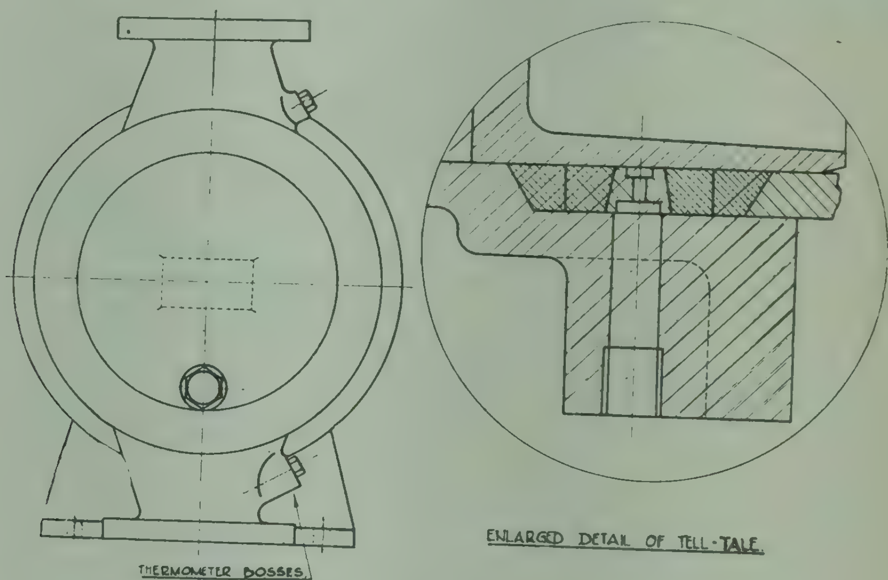


Fig. 22

transfer per unit period requires that the rate of flow of cooling water shall exceed the rate of flow of oil being cooled and that each gallon of water absorbs a relatively small amount of heat.

The following is a typical test of performance on a Gorton No. 180 cooler :

Oil flow, 13,900 lb. per hour.
Oil inlet temp., 131 degs. F. Outlet temp., 74 degs. F.
Water inlet temp., 54 degs. F. Outlet temp., 65 degs. F.

Heat given up by oil will therefore be :

Mass × Sp. heat × Temp. drop

$$13{,}900 \times .45 \times 131 - 74 = 356{,}535 \text{ B.T.U.}$$

Since this amount of heat has been absorbed by the cooling water, the rate of flow can be calculated by referring to the

temperature of the water at the inlet and outlet. These are, inlet 54 degs. F., outlet 65 degs. F.

$$\text{The water supply} = \frac{\text{total heat removed from oil}}{\text{Sp. heat of water} \times \text{Temp. rise}}$$

$$\frac{\text{Total heat from oil}}{1 \times (65-54)} \quad \frac{356{,}535}{1 \times 11} \quad 32{,}412 \text{ lb.,}$$

or 3,241 gallons per hour.

Each lb. of oil cooled, therefore, required 2.33 lb. of water to cool it. It will be seen that this type of cooler is most useful where the water supply is abundant and cheap. It is of the utmost importance that the water tubes be kept thoroughly clean on the outside as well as the inside. The continuous flow of oil past the tubes and the consequent drop in the oil temperature tends to cause deposits from the oil to cling to the tubes.

Chief among these deposits is stearine, a solid, white fatty compound found in most vegetable oils. Deposits of stearine will block up the oil pathways and prevent the cooler from functioning correctly.

CHAPTER VIII.

WHOLE CAKES, NUTTING AND MEALING

The cakes produced by the seed crushing mill are, with few exceptions, used for the feeding of animals and poultry. In certain circumstances, the cakes may be fed to cattle as single seed feed after reduction to particles of edible size. The finished product is known as nutted cake, the reduction of which may be carried out by the seed crusher or by the farmer himself.

Where the farmer prefers to make up his own compound feed, the cake may be supplied in meal form. It is safe to say, however, that by far the greater proportion of single seed cake is supplied to the compound manufacturer as whole cake, nutted cake or meal. The reasons for this can be quite easily explained. Compound feeding stuffs manufacture requires :

(1) A highly skilled knowledge of feeding requirements and of the items used in the compounds.

(2) Highly specialized machinery for reduction and mixing.

Few farmers have the time, skill or machinery for these operations, although there are those that pride themselves on their ability in this field.

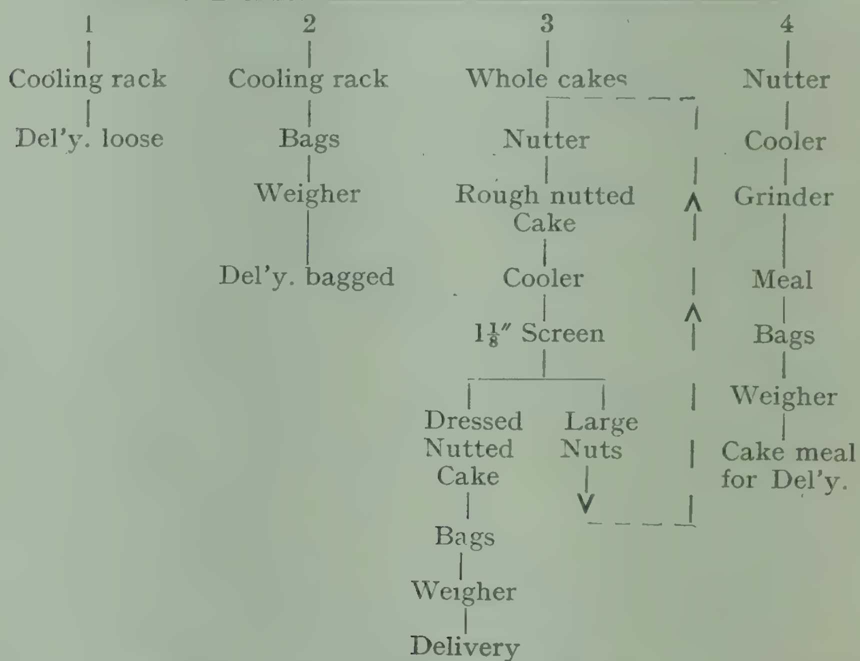
For the reasons outlined above, the seed crusher may be faced with a demand for each of the four groups enumerated below :

(1) Whole cakes loose.

(2) Whole cakes bagged.
(3) Nutted cake bagged.
(4) Meal bagged.

Before dealing with the machinery involved in the process necessary to produce the commodities enumerated, a general description of each is necessary. The chart below endeavours to set out as clearly as possible the sequence of treatment necessary to obtain each of these items :

HOT CAKES FROM HYDRAULIC PRESSES



(1) Certain types of cake are more suitable as single cake feeding stuff and among these, certain types are more suitable for dispatch as whole cakes. Chief among these are linseed and undecorticated cottonseed cakes.

On removal from the press, the cakes are at a high temperature and contain a fairly high moisture content. Dispatch in this condition would be very bad practice. The cakes, of course, must be weighed before dispatch, and apart from the tendency for breakage, the subsequent evaporation of the excess moisture in transit would cause loss in weight on arrival at the farm with its attendant complication.

The cakes are, therefore, cooled before weighing; they are cooled by placing them singly in racks for periods of one to three hours with a natural or forced air draught contacting all surfaces of the cake. In this way, the loss in weight due to moisture reduction takes place before weighing.

(2) For safer transit, the cakes may be placed into bags and weighed off at 1½ cwt. each. The number of cakes per bag will vary very much according to the type of seed and type of press used. Cakes from the Anglo-American press will run at 10 to

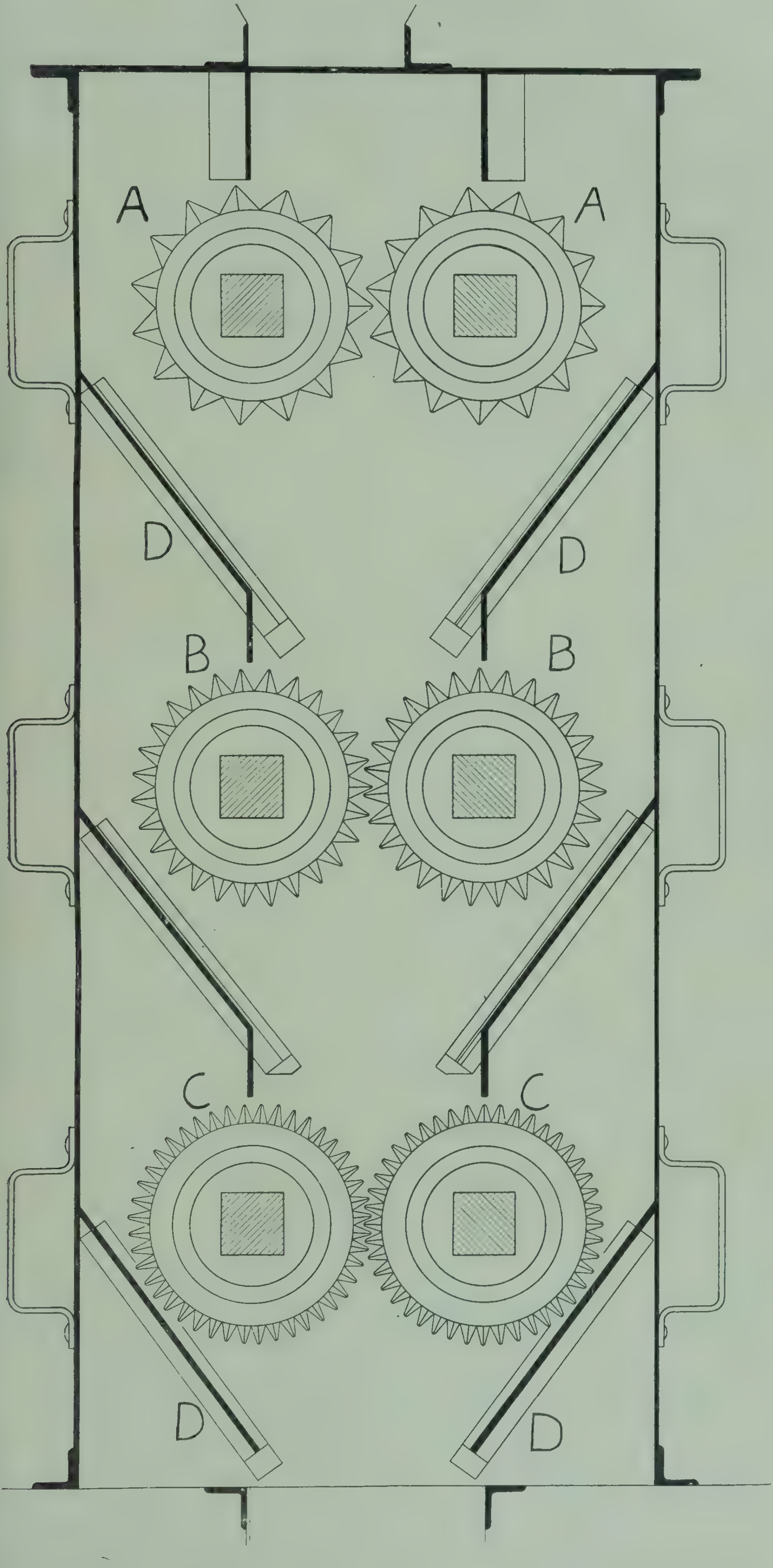


Fig. 23 Three Tier Cake Nutter

16 cakes per $1\frac{1}{2}$ cwt. Those from cage presses will exceed this number in most cases.

(3) While hot, the whole cakes are passed into a nutting machine and reduced to a particle size of approximately $1\frac{1}{8}$ inch maximum, any dimension. These pieces are known as nuts and at this size the cake is suitable for direct feeding to cattle.

To obtain uniformity of particle size, the nutted cake is passed over a $1\frac{1}{8}$ inch screen and the larger pieces which fail to pass through the screen are returned to the nutter with the new feed. The nuts which pass through the screen are conveyed to a cooler which reduces the temperature and drives off excess moisture. The cooled nutted cake is fed to bagging off plant. Most up-to-date installations combine bagging off and weighing in a single operation and the weighing may be automatic or semi-automatic. On removal, the bags are stitched and labelled for dispatch.

(4) The procedure is the same as in group (3) up to the point where the cakes have been nutted, but screening is not necessary.

Alternatively, a gannow may be used to obtain the reduction necessary where grinding is the final reduction. The grinder may be one of many types; chief among these are the Perplex and Bauer grinder. The former has one stationary and one rotating face, while the latter has both faces rotating in opposite directions. Bagging and weighing may be carried out on plants of the type used in group (3).

Fig. 23 shows a sectional view of a cake nutting machine. Three sets of cracking rolls are built up by means of a series of cast steel spiked discs. The discs are fitted on square sectioned shafts and tightened by means of a locking ring at one end. The coarse spikes on the top set of crackers (A) perform the initial breaking. The rough, broken cake is next passed via the guide plates (D) to the secondary crackers (B) for further reduction, and after passing through the final crackers (C) is ready for screening and cooling.

CHAPTER IX.

CAKE COOLER

The cooler shown in Fig. 25 is used for the treatment of nutted cake. The hot nutted cake enters the cooler inlet (A) and runs over the perforated cone (B). On leaving cone (B), the cake travels over the inner face of the inverted cone (C). The perforations are $\frac{1}{8}$ or $\frac{3}{16}$ inch size, and the finer particles of cake pass through the cones to an air seal feed roll at exit (E).

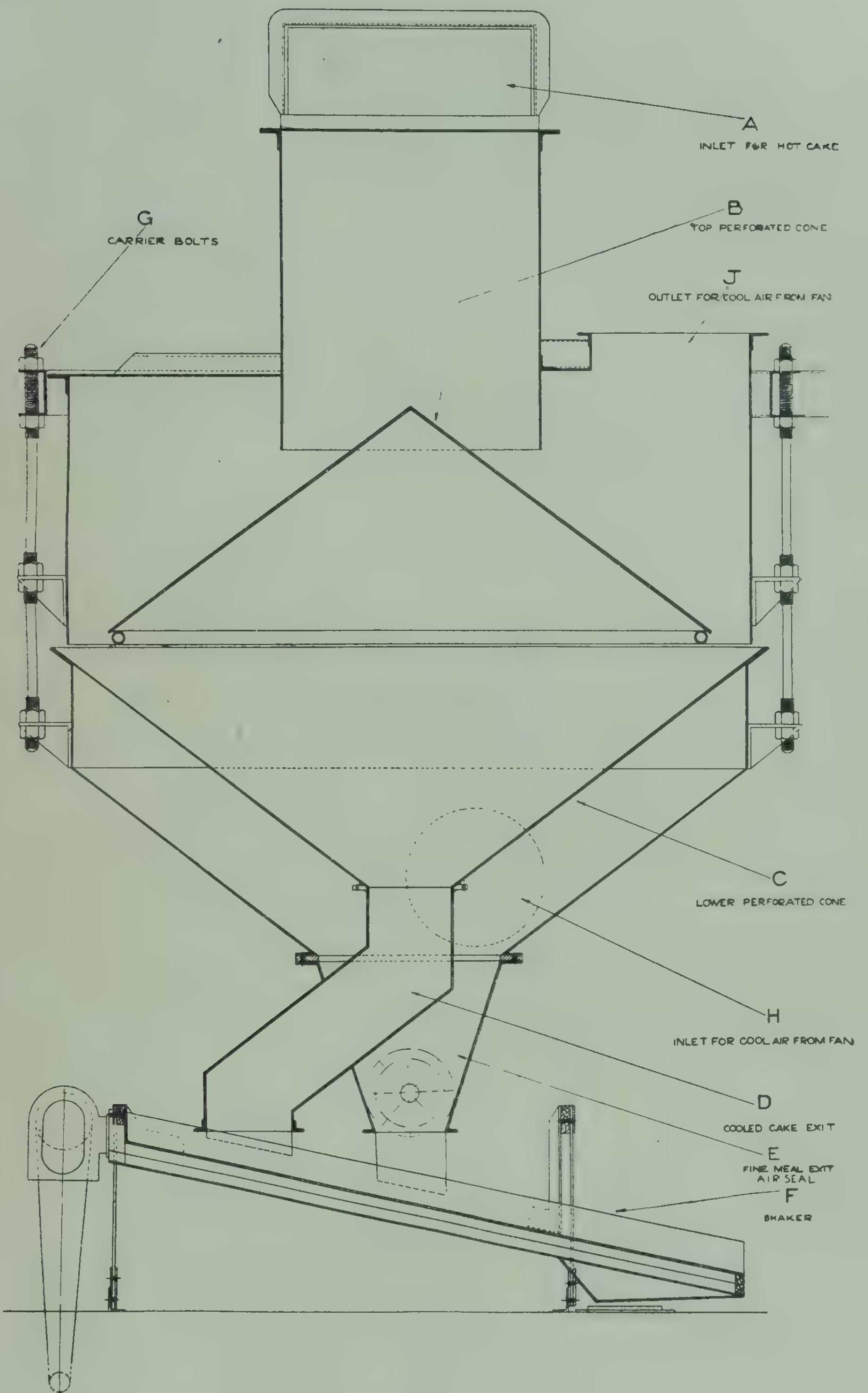


Fig. 24 **Section of Cooler**

The nutted cake is, of course, retained by the cones until ejected at the exit (D). The cooling medium is air supplied and ejected by means of fans. Air is forced into the lower chamber of the cooler at the inlet (H) and passes through the perforation of the lower cone, where a full layer of nutted cake is disposed. The air then passes through the layer of cake and

upwards to the inner face of the top cone. On passing through the top cone and the layer of cake lying on this cone, the air is sucked away by the second fan connected to the outlet (J).

The used air, which, having passed through the layers of nutted cake is now warm, contains a fair amount of very fine meal, and before this air can be passed into the atmosphere the dust must be removed. To effect the dust separation, the used air is passed through a filter.

The filter consists of an upper and lower chamber connected by a series of tubes of porous fabric. The air, on entering the upper chamber, passes downward through the tubes into the atmosphere via the pores in the fabric. The dust is trapped on the inner surface of the tubes and is collected in a hopper below.

The nutted cake emerges at the exit (D) via a controlling

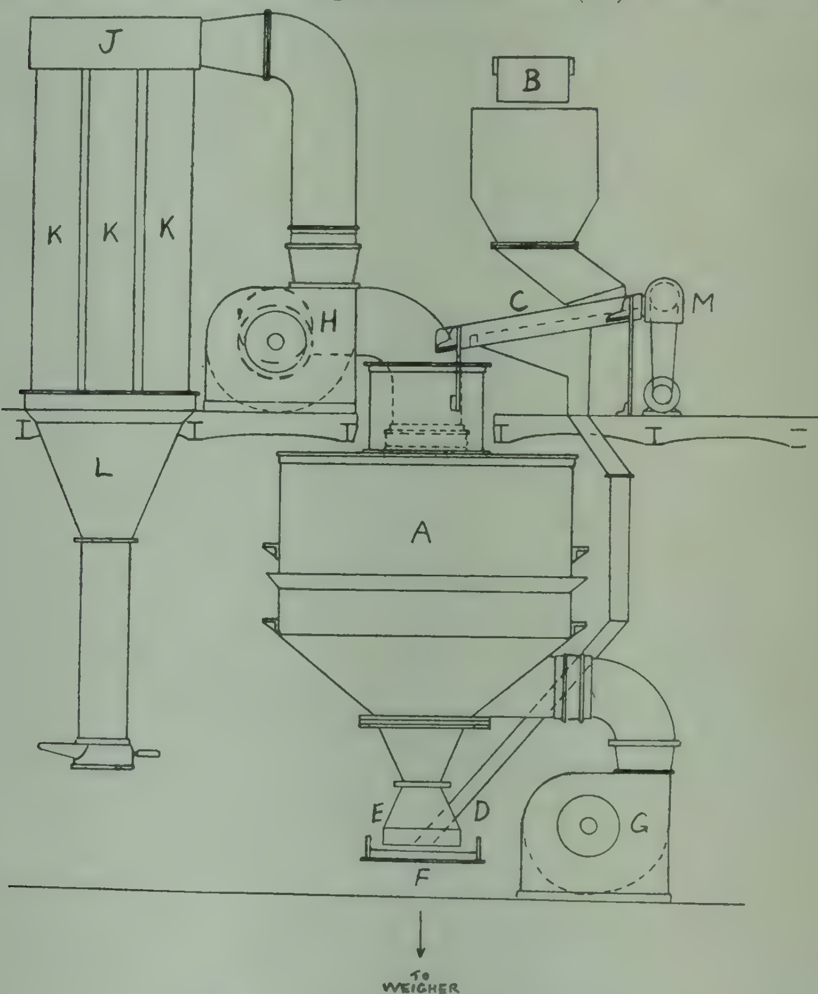


Fig. 25 Complete Cooling Unit

sleeve which can be raised or lowered by the operator. In this way, the rate of discharge can be controlled and a full cooler guaranteed. It is absolutely necessary that the cooler be kept full in order to ensure that the air travels through the cake layer. Should any part of the cones become free of cake, the air will

escape at this point and the cake will be by-passed. The nutted cake, plus the fine meal from exit (E), pass through the 1⅛ inch screen (F), and on to the bagging and weighing unit, while any large pieces which cannot pass through the screen are returned with the raw cake to the nutter.

The depth of the cake layer on the upper cone surface can be varied by raising or lowering cone. The cone mounting is not shown on the diagram and consists of four suspension rods secured from the cooler top and hooked round the tubular steel base support. The depth on the lower cone is controlled by lowering or raising the lower portion of the cooler.

Figure 25 shows more completely the cooler auxiliary plant. The cake has been nutted and passed to a bucket elevator (B). The buckets are automatically tipped and the cake discharged into a hopper feeding the preliminary screen of ¼ inch size holes. The coarse meal, which passes through the screen, by-passes the cooler and rejoins the main stream, via the pipe (D).

The fan (G), turning at 770 r.p.m., forces cool air into the cooler chamber at 5,000 cubic feet per minute, while the suction from (H), travelling a little faster, can remove air at 5,500 feet per minute. This arrangement maintains a slight suction at all joints and prevents unnecessary passage of dust into the atmosphere.

The fabric tubes, or stockings (K), are six in number and each measure 8 feet in length by 15 inches diameter. The air diffusion surface is therefore 200 square feet. In removing or absorbing heat from the cake, the air also absorbs a good deal of moisture. The amount of moisture removed depends upon many factors, among which are moisture in hot cake, moisture in the atmosphere, temperature of cake and air, and temperature of cooled cake. The final moisture in the cake is naturally controlled by the features stated above. Details of actual moisture behaviour will be dealt with at a later date.

The plant described will treat approximately 5 tons of nutted cake per hour at a temperature of 130 to 140 degs. F. The temperature of the cooled cake should be below 90 degs. F. A great quantity of air has to flow through the fans and the cake in the cooler. Because of the large size of the cooler, the velocity of the air will be fairly low and this aids the task of taking up heat, but in addition reduces to a minimum the amount of small particles taken up. The velocity of air in the fan trunking should not exceed 2,000 feet per minute. The division of particle sizes, i.e., nutted, large nuts and meal are, of course, only temporary, and one single commodity consisting of nutted cake containing its meal eventually reaches the drawing off spout.

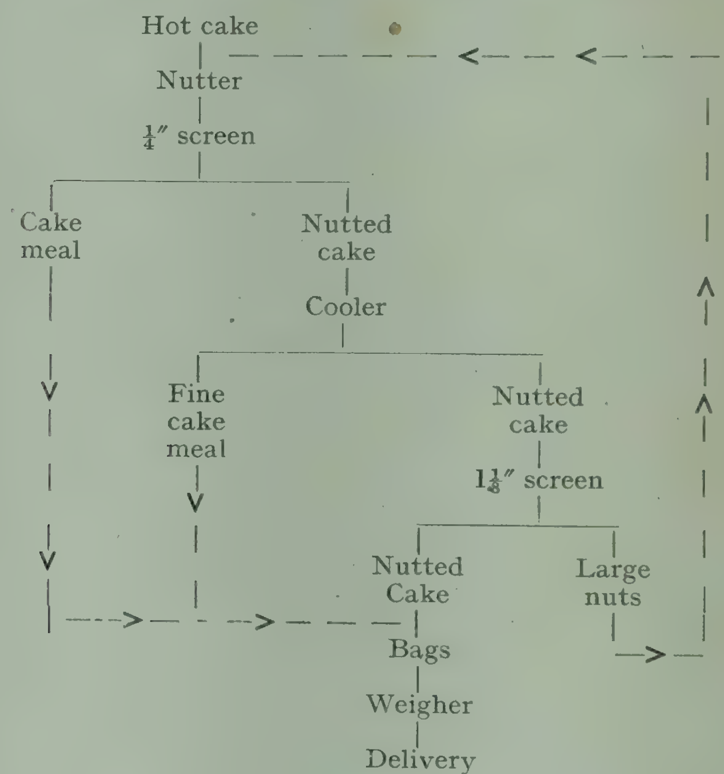
The purely manual operation of drawing off and then weighing on a beam scale has in most cases been superseded by

the semi-automatic or fully automatic operation, but the actual releasing of the bag from scale hopper or plain spout is essentially manual.

Should experience show that loss in weight is unavoidable after weighing, this can be offset by making the necessary allowance on the scale. This is more likely with palm kernel nutted cake than with any other.

On studying the foregoing description of the cooling operation, the reader may note that the sequence shown as group 3 of the four groups shown in the previous chapter is not now detailed sufficiently. The meal which has inevitably been produced in the nutting operation cannot be treated effectively by the cooler, and therefore is removed beforehand. Furthermore, a small quantity of very fine meal has been removed by the air current.

The sequence may therefore be charted more accurately, thus :



CHAPTER X.

WEIGHERS

Semi-Automatic

Nutted cake, after cooling, is weighed and drawn off, or drawn off and weighed. The order of the two features depends upon the method of weighing in operation. Weighing methods fall into three different categories : (1) Hand weighing ; (2)

Semi-automatic; (3) Automatic weighing.

HAND WEIGHING.

In this case, the nutted cake is passed into a fairly large container which terminates with a drawing off, or bag holding spout. The bag is held on the lower end of the spout by means of a quick release belt When the bag is secure, the operator

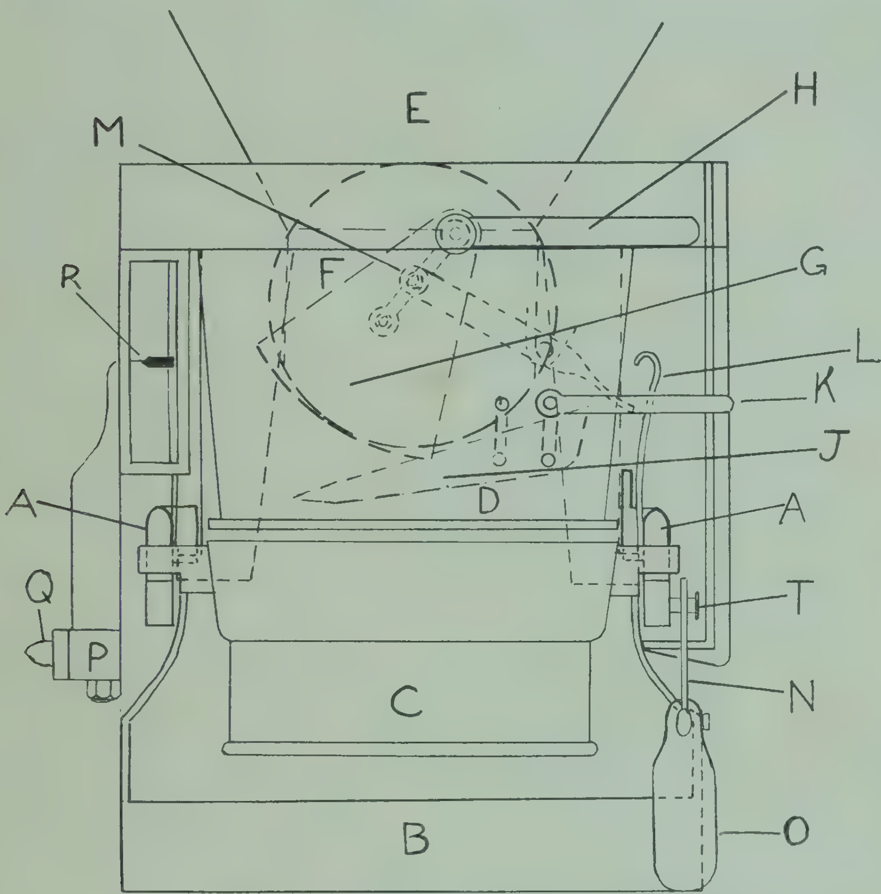


Fig. 26 **Front Elevation Semi-Automatic Weigher**

a. Twin beam suspension.
b. Weight pan.
c. Movable bag spout.
d. Fixed delivery housing.
e. Cake hopper.
f. Main feed chamber.
g. Main feed gate.
h. Feed gate control handle.
j. Manual trickle feed chute.
k. Manual trickle feed chute control handle.
l. Toggle breaking arm.
m. Toggle for holding "G" at open position.
n. Balance weight lever.
o. Balance weight.
p. Bag spout clamp.
q. Bag spout clamp handle.
r. Correct weight indicator.
s. Beam pivot.
t. Contact stud for balance weight lever.

opens a slide which allows the cake to pass into the bag. When the bag contains approximately the correct weight, the slide is pushed back into place and the bag is released and taken to a beam scale. This scale is probably too well known to require description and though considered old fashioned compared with

high speed plants, is nevertheless much used at the present day.

One of the pans of the scale contains the weights. The most popular weight for dense cake is $1\frac{1}{2}$ cwt. nett, but materials like palm kernel cake are usually weighed at smaller amounts like $1\frac{1}{4}$ and 1 cwt.

A levered hook is used to hold the weight pan up while the cake pan is empty, and released when the weighing operation is about to commence. After weighing the weight pan is again secured and the weighed bag removed from the scale and stitched.

Accurate weighing at speed calls for considerable skill and the trend, therefore, is to simplify the operation as much as possible. The semi-automatic weigher is easy to use and economical from the labour aspect. By its means, the bag is

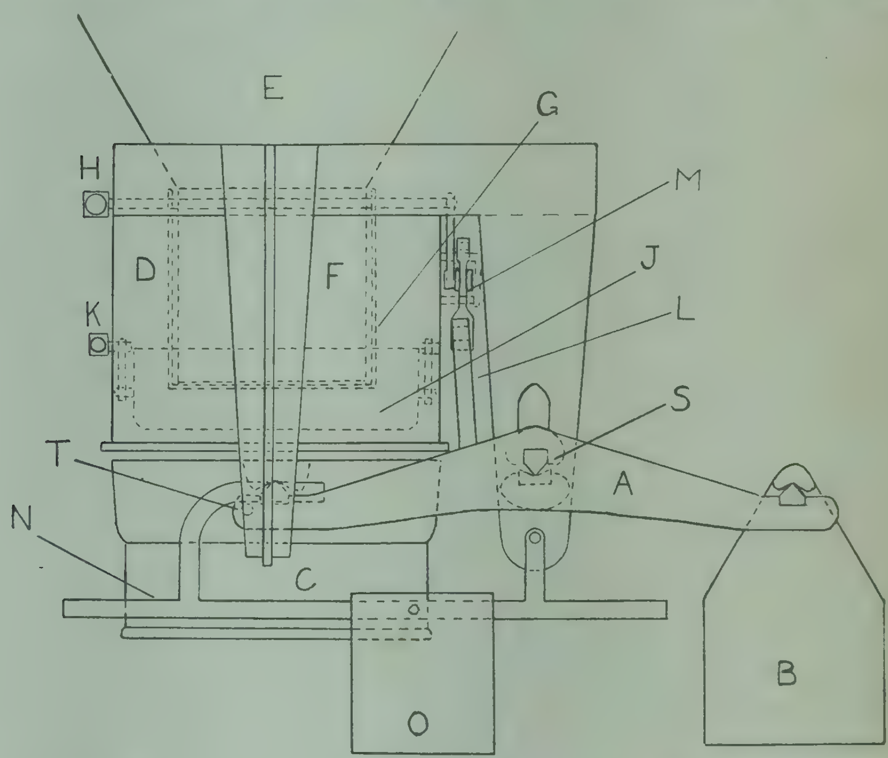


Fig. 27 **Side Elevation Semi-Automatic Weigher**

weighed while still suspended from the filling spout and only removed after the correct weight has been obtained.

SEMI-AUTOMATIC BAG SCALE.

The weighing mechanism is similar to that of any other beam scale. A double beam (A) pivots on knife edges mounted on arms which project downwards from the cast iron carrier frame below the collecting hopper.

The weight pan (B) contains the number of weights necessary for the particular run of nutted cake and is suspended from the beams by knife edge, as also is the cake spout (C). The upper portion of the cake spout (D) is secured rigidly to the

hopper (E) and in this spout the feed control mechanism operates. The feed gate (G) is opened by the operator and closed automatically by the downward travel of the bag spout (C). The automatic mechanism consists of a small vertical arm (L) in conjunction with the toggle (M).

The balance weight lever (N) and balance weight (O) cause the toggle breaking mechanism (L) to function ahead of the final weigh. The trickle feed chute (J) is manually operated and controls the final trickle of cake to put the beam in equilibrium. The bag spout clamp (P) secures the spout during the intervals of removal and fitting of the empty and full bags.

Operation

Nutted cake enters the hopper surmounting the scale and is effectively held by the main feed cut-off.

An empty bag is attached firmly to the movable bag spout by means of a securing belt and the handle (H) is depressed. The movement pushes the cut-off out of position and cake pours into the empty bag. The new position of the cut-off is sustained by the toggle (M) which locks the pivoting shaft.

The cake will continue to drop into the bag until the downward movement on the bag side of the scale, due to the weight of material, cause the arm (L) to break the toggle (M). At this point, the weighment is probably about 2 lb. short of final correct weight and the feed gate (G) has dropped to its closed position when no longer sustained by the toggle.

The operator then agitates the handle (K) and a small feed drops in the bag from the trickle chute (J). The balance weight at the side is still influencing the weigher beam, but as the weighment approaches completion, the beam passes below the influence of the balance as the balance weight frame becomes anchored on a projection on the side of the weigher. If the position of the balance weight is correct on its lever, this should coincide with the last trickle of feed into the bag. Meanwhile, the needle or correct weight indicator (R) has been under observation by the operator, and by its means he is aided in bringing the weigher to equilibrium.

The clamp (P) is then pulled into position under one arm of the weigh beam and the securing belt then released. The full bag then drops to a truck which is placed in a position below the bag and the bag is swiftly removed to the store mill and there stitched neatly and labelled for dispatch.

The position of the weight (O) is very important and must be determined by careful observation. This scale is also suitable for ground cake meal and many other commodities. The weigher can be adjusted rapidly to weigh lighter amounts by simply removing the surplus amount from the weight pan.

Automatic Weighing

The bagging-off operation is linked essentially with weighing, as at this stage the nutted cake or meal is about to be delivered to the compound manufacturer. In some cases, however, the compound mill is situated near to the oil mill and the nutted cake can be delivered by worm or scraper conveyor. In this case, of course, it is not necessary to bag off the material, but none the less the cake must be weighed.

The fully automatic weigher may be used for either of these operations with equal success. This scale is capable of weighing at 2 cwt. per tip or less, according to the density of material used.

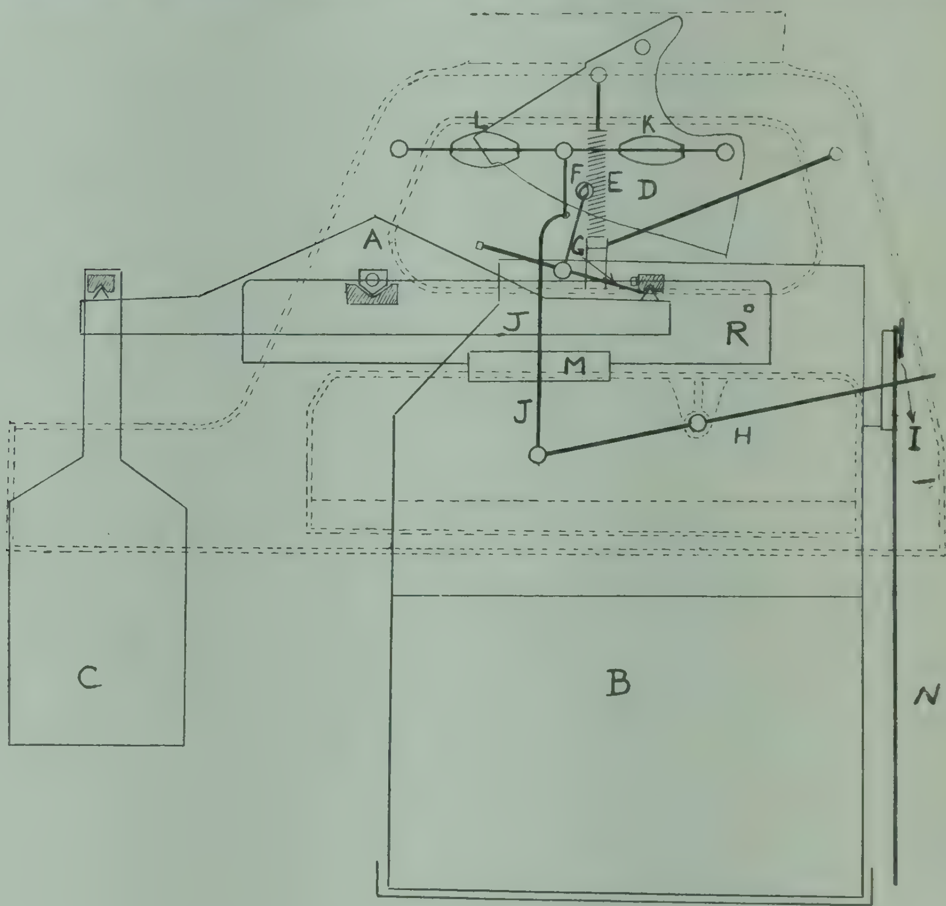


Fig. 28 Automatic cake and meal weigher

Fig. 29 shows the weigher with the feed gate held open. The gate is held by the upward push of the empty weigh bucket against the spring (E); the levers (L) and (K) are held in their upward position by the feed gate connexion.

As the nutted cake flows into the weigh bucket, the increasing weight in the bucket causes a slow downward movement. This downward movement soon reaches the limit of influence of the pendant spring (E) which no longer sustains the feed gate. The feed gate, therefore, has also closed somewhat and the drop

bar (J) is lowered until it rests on the prop (F).

The feed has by now dropped to a comparative dribble and a further downward movement of the weigh bucket causes a

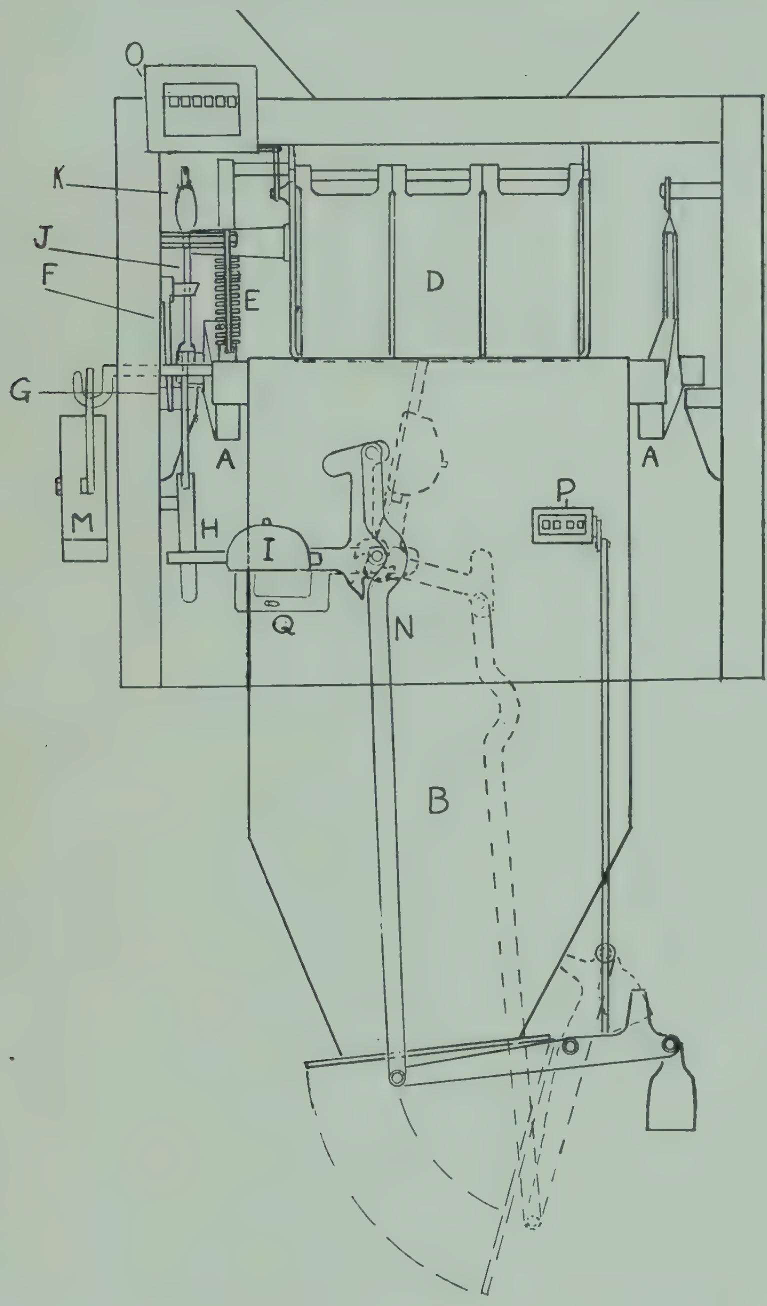


Fig. 29 Front view, showing two positions of weigh bucket exit door

series of movements to take place. The trigger (G) is depressed by a projection on the weigh bucket and the trigger lever holding the drop bar is withdrawn. Simultaneously, the balance weight (M) is disengaged and the bucket registers equilibrium with the weigh pan. The movement of the drop bar operates the knock-off lever (H) and the striking bolt is knocked upwards. The upward movement breaks the toggle which has been holding

the exit door of the weigh bucket in the locked position.

The exit door is opened by the weight of the contents of the bucket and the weighment is immediately discharged. When the bucket is empty, the counter weight causes the exit door to close once more and the toggle is reset. The same movement causes the striking bolt to fall back into its original position and the lock caused by the levers (L) and (K) is broken.

The upward movement of the empty weigh bucket once more exerts a pressure on the spring (E) which keeps the gate (D) open once again.

To ensure that the feed gate and exit door shall not at any time be opened simultaneously, the lock (Q) shoots forward under the knock-off lever when the toggle breaks and the exit door is opened. The lock prevents a possible downward movement of the lever (H); the drop bar (J) is prevented from rising and allowing the feed gate to open.

The balance weight (M) has not so far received much attention. This balance weight is adjusted on its carrier frame until it represents the weight of material in suspension between the feed gate (D) and the weigh bucket. This amount, of course, is not registering while in suspension, and must be allowed for accordingly. The balance weight, however, must not be allowed to operate once the suspended cake has come to rest in the weigh bucket, and to prevent this, the frame is caught on an obtrusion on the main frame of the weigher.

The weighment can be checked by sliding the striking bolt back so as to miss the upward stroke of the lever (H). A pointer on the beam (A) should project exactly opposite a fixed pointer on the frame if the correct weight is in the bucket; any deviation from this position indicates over or under weight according to which side the pointer rests.

Subsequent weighment can be corrected by moving the compensating weight (M) on its frame or carrier to increase, or decrease its influence on the movement of the bucket. This has to be done by trial and error. Variations in the speed of flow of the cake tend to alter the accuracy of the scale and a steady flow is therefore advisable. Upon discharge, the weighment may be passed either to a conveyor or a drawing off spout for bagging. In the case of drawing off in bags, it is essential that each weighment be moved before the next is released. Each time the feed closes, the counter or recorder (O) registers, and each time the exit door opens, the counter (P) is operated. These counters are therefore in the nature of a check on each other.

CHAPTER XI.

GRINDING MACHINERY

The chapters dealing with treatment of oil cake would not be complete without a reference to grinding machines. Nutted

cake is convenient for transportation and feeding direct to cattle, but if the cake must be combined finally with other cakes and other materials, this cannot be done satisfactorily without first reducing to meal form. Reduction of comparatively hard cake requires considerable force before the large pieces can be thoroughly disintegrated. It is necessary that the cake shall be retained in the machine until efficiently reduced, as uniformity of particle size is a very desirable attainment.

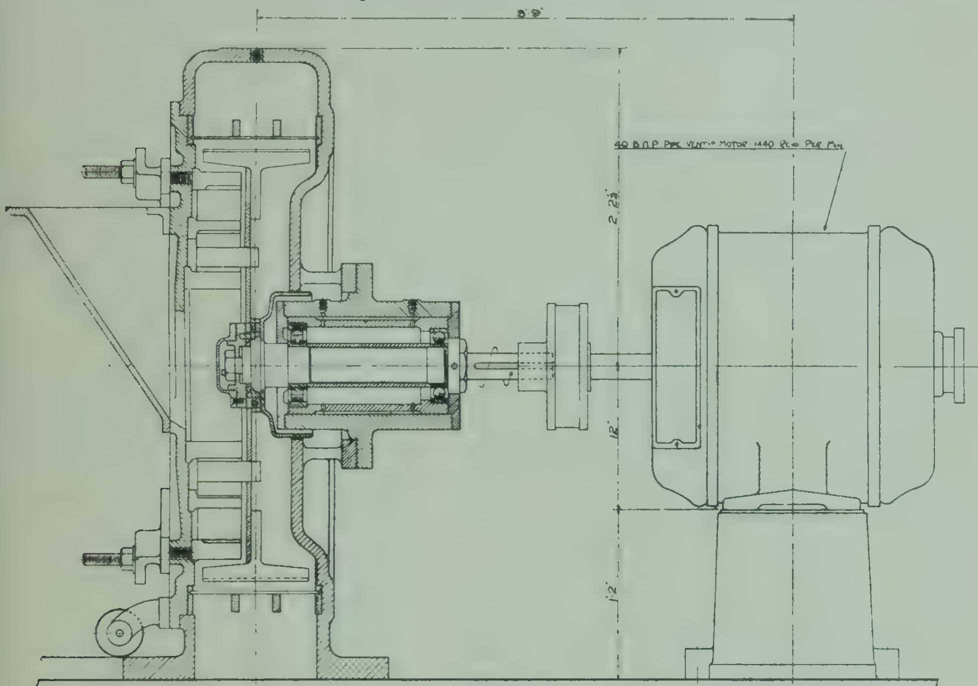


Fig. 30

Sectional arrangement of the Perplex Grinder

Certain grinders attain this uniformity by screening within the carcase of the machine, while for others screening is carried out after grinding and the overtails are circulated for regrinding. The screen sizes are important as they can be used to set the standard of grinding required, providing the correct feeding rate is applied.

The grinders most commonly used in an oil mill are those falling within one of the categories of impact or percussion machine, of which one example is the "Perplex" (Fig. 31) illustrated. This machine has a rotating plate fitted with three sets of obtruding studs mounted on a horizontal shaft which is directly connected on the outside with an electric motor. On the periphery, four stout, short cross bars are also fitted. The purpose of the cross bars is to sweep the closely enveloping screen. The door or stationary panel is equipped with three sets of deeply castelated rings which describe circles immediately outside the circles described by the rotating studs. The inlet hopper approaches the centre of the door and the cake is thrown

outwards by centrifugal force by the inner line of studs. Such is the speed at which the studs travel that the cake is caught between the studs and the castelated rings and smashed into smaller pieces. The small pieces pass fairly easily through the first ring where the action is repeated.

The intervals between the castelations on the outer ring are very small and only fine particles can pass through. If fine enough, the particles are passed through the enclosing screen with force, and if not small enough for this are soon reduced by the cross bars which operate between the outer ring and the screen. The inlet hopper has a magnet immediately above on which possible tramp iron or stray nuts and bolts are caught. This is a very necessary precaution as the presence of these bodies in the machine is highly dangerous.

To maintain dust concentrations above the explosive limit, the displaced air in the carcase may be circulated back into the

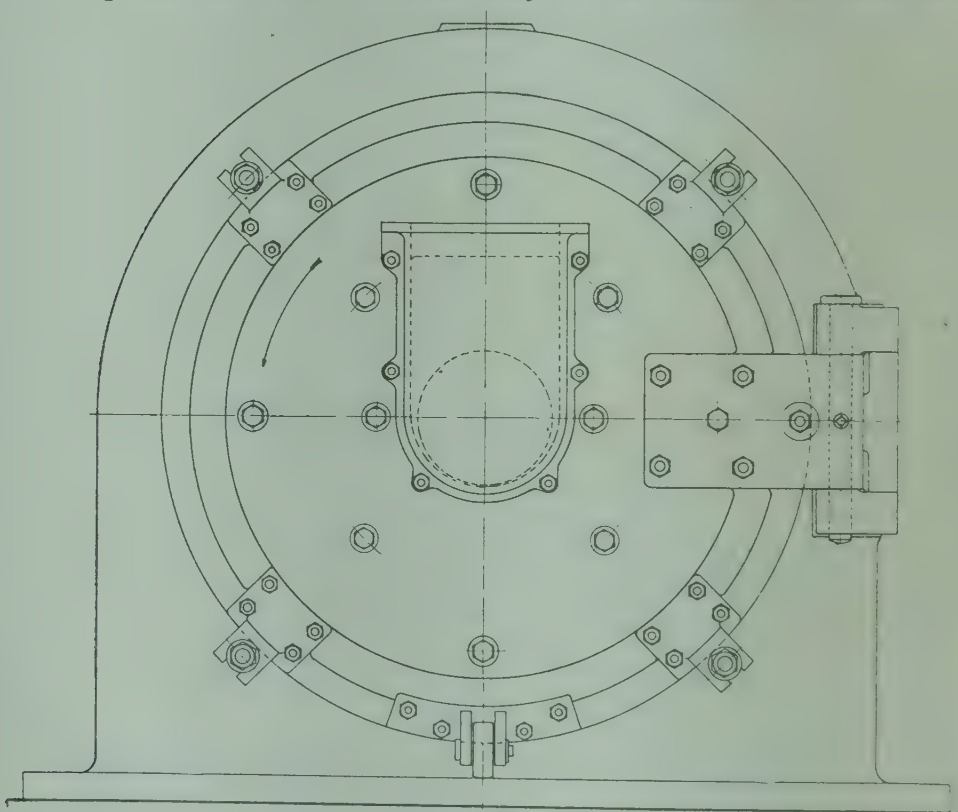


Fig. 31

Side Elevation of the Perplex Grinder

inlet chamber. A large size " Perplex " requires a 40 h.p. motor which travels at about 1,450 to 1,500 r.p.m. The throughput obviously depends upon the hardness and toughness of the cake, but the average performance using a No. 2 screen is approximately two tons per hour. The screens can be changed rapidly to suit changes in requirements. The spare screens are assembled

in panel form between steel discs and individual panels can be replaced easily without disturbing its neighbouring panels.

The standard screen range is as follows :

Nomenclature.	Hole size.	Gauge of plate.
Pin point	$1\frac{1}{2}$ mm.	18
Pin head	2 mm.	16
No. 1.5	$1\frac{1}{2} \times 13$ mm.	14
2	2×12 mm.	10
3	3×20 mm.	10
4	4×20 mm.	8
5	5×20 mm.	8
6	6×20 mm.	8
10	10×25 mm.	8

In addition, certain large circular holed screens are used for grinding raw palm kernels and copra. These include $\frac{1}{2}$ inch, $\frac{5}{8}$ inch and $\frac{3}{4}$ inch diameter.

The Bauer Grinder

Cake reduction consists of a shearing or cutting action at high speed. The chief distinctive feature is that while most grinders consist of moving beaters opposing stationary projections or a rotating face opposing a stationary face, the Bauer grinder, which may be included under the heading of attrition mills, is equipped with two opposing rotary grinding faces.

The sectional view of grinder (Fig. 32) shows that each face is fixed directly to the extended shaft of an electric motor. The actual grinding surfaces are specially designed to give the maximum efficiency. Each face consists of six sections bolted to a carrier plate. The sections are completely covered with a series of rectilinear depressions about $\frac{1}{4}$ inch deep. The " land " surrounding the depressions forms the cutting edges which perform the actual grinding.

The left hand grinding face has four large openings in the centre to admit the feed of cake, and a cross bar in the dished centre of the right hand plant helps to drive the cake into the space between the faces. The inflow of cake is via a magnet (not shown) and feed roll driven by separate motor. The clearance between the grinding faces must be varied to suit changing requirements and the operator can achieve these variations easily and rapidly. The clearance is not constant, but diminishes slightly towards the outer periphery of the plates. The feed is thereby encouraged to enter the larger inner space while the diminished clearance provides the final grinding. The diagram indicates the method of carrying the grinding plates.

The left hand motor shaft is secured to a fixed bearing at the thrust or outer end, thus preventing any movement outward due to the pressure exerted between the plates. The inner bearing of this motor is secured to the shaft but is able to move slightly

when the shaft expands due to heating. The right hand grinding plate is adjustable and the equipment provides for accurate setting up. The outer thrust bearing in this case is carried in a separate housing within the main housing on the motor carcase. The internal housing can be moved forward or backward by turning the setting pin in the required direction until the correct clearances are achieved. The setting pin is not threaded in the main housing as may be supposed, but turns in a cross bar behind the housing. The cross bar is linked with a hand operated levering device by means of which the shaft can be withdrawn for a distance of $1\frac{1}{2}$ inches. The vertical position of the lever throws the shaft to its full forward position, whilst depressing the lever allows the spring loaded bar to extend to its outer limit.

The throw-out mechanism is used when the machine is about to be started. The machine is started when the extra clearance operates, and the movable plate is slowly levered into the closed position afterwards. This is a safety device in the event of faulty plate adjustment and also affords a means of inspecting the grinding face.

Inspection of the plates involves stopping the machine, retracting the movable shaft and opening the machine carcase by withdrawing the clamping bolt and pulling the hinged sections back. Each motor is 50 h.p. and travels at 1,400 to 1,500 r.p.m. The peripheral speed at the outer grinding limit is

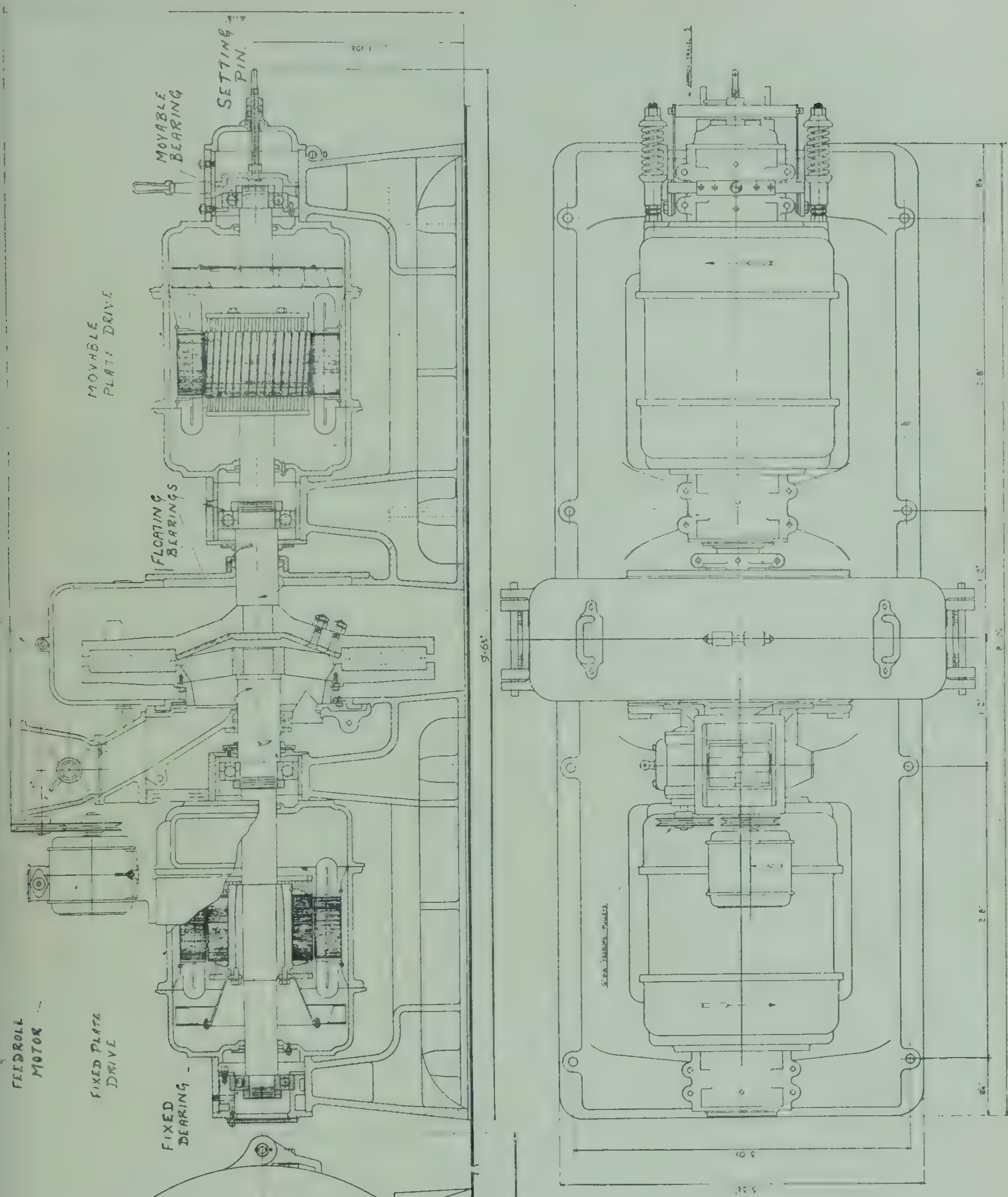
$$\pi D \times 1{,}500 = \frac{22}{7} \times 3 \times 1{,}500 = 14{,}140 \text{ ft. per minute.}$$

The speed differential at this point, therefore, equals 28,280 ft. per minute.

This machine is particularly useful for reducing all grades of cottonseed cake and does not become choked by the presence of cotton linters therein. The linters are expelled simultaneously with the cake meal and can be separated easily by screening afterwards.

The output will vary according to the fineness of grinding and also according to the consistency of the cake, but an approximate average performance is seven tons per hour. The cutting edges on the grinding faces tend to wear on the forward side only and can be blunted in 24 hours. The machine, therefore, should have the motors reversed after 24 hours wear, when the opposite edges will be brought into play. The new direction tends to sharpen the back cutting edges and the machine can again be reversed for the following 24 hours. In this way, the grinding faces can be used for a very long period before being scrapped.

The grinding operation often results in loss of moisture in the cake, and this is an aspect of grinding processes which will require future study.



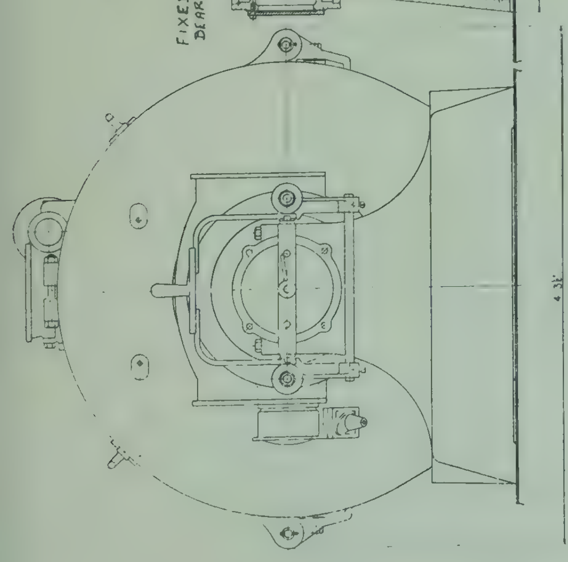


Fig. 32 End, sectional and plan views of the Bauer Grinder.

CHAPTER XII.

SOLVENT EXTRACTION

The solvent extraction process has made much progress within the last 50 years and this process is felt by many people to be superior to expelling or hydraulic pressing. It would be quite wrong to hold any sweeping views on this point, however, as there is much to be said for the screw press or expeller. Moreover, the tendency at the present time is to link the processes of expelling and extraction in order to derive the maximum advantage from each.

The solvent extraction operator does not usually treat high oil content seeds by means of a single extraction process, but prefers to remove the bulk of the oil by means of expellers. Most part-expelled cake, containing probably less than half of the original oil content, is an ideal subject for treatment by the solvent extraction plant.

The principle underlying the extraction process is that certain liquids of the hydrocarbon group possess a powerful affinity for oil. Oil is readily dissolved in these liquids without undergoing any chemical change, and can be separated later by distilling the solvent. The solvents are many and varied, but for various reasons only a few are used on a commercial scale. Besides having the ability to dissolve oil, a solvent should have a fairly high vapour pressure. This means that the liquid will readily become gaseous under the right conditions and, in so doing, will be recoverable from the extracted oil.

The chief solvents in use by the vegetable oil industry are petrol (boiling range 75-95 degs. C.), and trichlorethylene (boiling point 86.7 degs. C.).

Trichlorethylene is a more powerful solvent than petrol and is non-inflammable. Since trichlorethylene is non-inflammable, the stringent safety measures necessary for petrol do not apply.

The products of petroleum distillation are fractional, which means that the vapours are recovered at various ranges of temperature. The vapours recovered at low temperature have a very high vapour pressure, and the resultant liquor is easily vaporized again.

In actual plant practice, a very high vapour pressure is a disadvantage, as the tendency for leakage of solvent to atmosphere is increased and the losses raise the cost of processing. On the other hand, a low vapour pressure requires a greater amount of heat to accomplish vaporization. Therefore, it would appear that the choice lies between increased solvent losses and increased steam consumption. For this reason, the fraction obtained at 75 to 95 degs. C. is regarded as the best range for the extraction process. Trichlorethylene has a fixed

boiling point which is the average of the above petrol fraction.

Moisture loss in the process is usually nil, and this is important since complete expelling frequently results in considerable moisture loss. The final moisture in extracted meal can be controlled very accurately by the drying system. Live steam applied at the end of the processing puts up the moisture content to as high as 20 or more per cent., and this has to be reduced by the application of dry heat.

In the past a good deal of hostility was met on the part of those industries which used the products of extraction, namely, the oil refiner and margarine and cooking fat manufacturers on the one hand, and the compound feeding stuffs producer on the other hand. Possibly, a deal of this hostility was due to prejudices, but it must be admitted that in the earlier attempts at extraction, the oil and meal residue was not always free of traces of the solvent. To-day, there is little risk of the presence of the solvent in either the oil or meal, and this is mainly due to increased efficiency in the finishing processes and in the use of pure solvents.

The cost of solvent in the operation is fairly considerable, and efforts are continually being directed towards a reduction in the loss. Most extraction plants nowadays have reduced solvent loss to as low as two gallons per ton of seed processed, while some plants show lower than this figure. Although the solvent loss is partly a function of the particular plant, it is also influenced by the type of materials being processed, since some materials are more economical than others. The extraction process does not require that the seed meal be cooked and, therefore, it is not subjected to such high temperatures as those necessary for expelling and hydraulic pressing, although the oil is subjected to a fairly high temperature by the application of live steam at the point where the last traces of solvent are removed from the oil. Live steam, however, is not as harmful to the quality of oil as is jacket steam. Perhaps the main advantage enjoyed by the solvent process is that the residual oil in the extracted meal is frequently lower than 1 per cent. of the meal.

Since the value of oil is many times greater than that of the meal or cake residue, it will be seen clearly that a low residual oil is very desirable.

The chart below sets out the comparison of oil yields between expelling and extracting for palm kernels :

	Expelling. Per cent.	Extraction. Per cent.
Oil in raw material	49	49
Oil in residue	6	1
Oil removed (to total seed) ...	45.75	48.49
Oil removed (to total oil) ...	93.36	98.96

The residue or extracted meal is used extensively in the manufacture of compound feeding stuffs. The low oil content of extracted meal is usually offset by blending with meals produced by hydraulic pressing and/or expelled cake.

CHAPTER XIII.
LABORATORY SCALE
Extraction of Oil Seeds

The best introduction to the extraction process is, perhaps, a description of the Soxhlet method. This method can, for our own purposes, include minor variations of the original Soxhlet tube. The original Soxhlet tube is constructed with the object of obtaining complete immersion of the charge in the solvent. The solvent, plus oil, is passed to the container by means of a syphon tube at the side.

The accompanying illustration shows a simplified tube in which complete immersion does not obtain.

Both of these methods are used in laboratory work where small scale extractions are carried out for various purposes, including the determination of the amount of oil contained in a given sample of seed or oil cake.

The oil bearing subject is reduced by milling or pounding to a fine particle consistency, after which a small quantity of the resultant meal is weighed and carefully wrapped in a filter paper. The amount of meal used is usually 3 gms. The sample, in its paper container, is then placed in a special tube with an

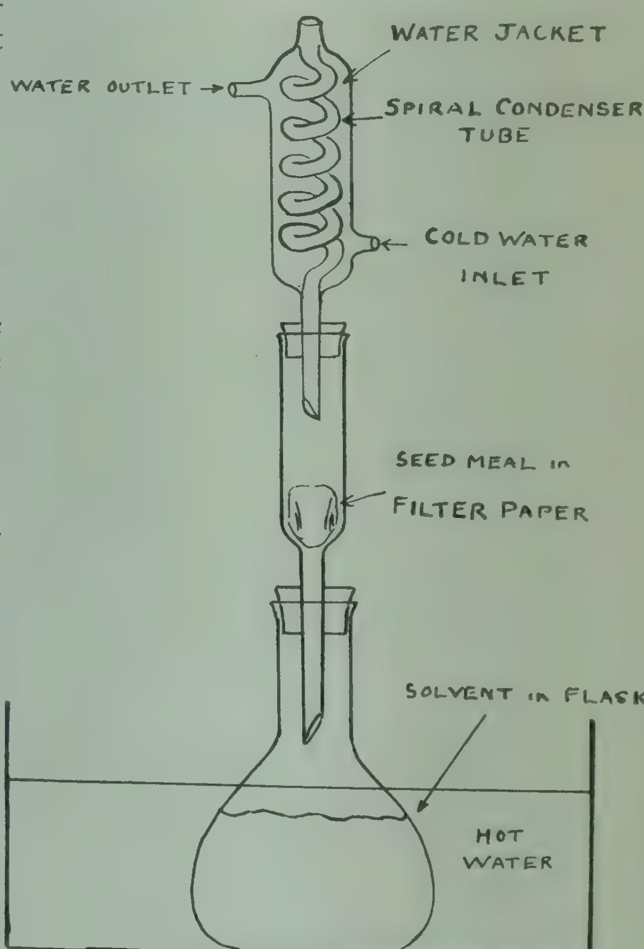


Fig. 33 Soxhlet Tube

inverted bottleneck. A quantity of solvent, in this case petrol, is then poured into a weighed flask; the bottleneck tube is connected to the flask by means of a tight fitting cork. By the same means a water jacket condenser tube is inserted above the bottleneck tube. The lower portion of the flask is then immersed in hot water.

Owing to its high vapour pressure and the heat from the hot water bath, the petrol is readily evaporated. The petrol or other solvent vapour rises, and, passing round the paper carton, reaches the condenser tube at the top. Condensation results from contact with the water cooled surface, and the liquid flows back down the tube to the paper carton. The solvent is readily absorbed by both the paper and meal, and some of the oil contained in the meal is dissolved.

The flow of the solvent is continuous, as evaporation is continuous, and the solvent-containing oil drains away from the carton and back into the flask. The oil cannot evaporate, of course, and only pure solvent vapour leaves the flask on the upward journey to the condenser tube.

After two hours of continuous evaporation and condensation of the solvent, nearly all of the original oil has been dissolved and removed from the meal. The meal and paper are then removed from the tube, and after further pounding the meal is again enclosed in the filter paper and returned to the tube.

A further two hour period of continuous extraction ensures that the meal is absolutely free of oil and that the oil is now concentrated in the solvent in the flask. The paper and meal are then removed and a non-return container is fitted to the apparatus. The evaporation of solvent is then continued, but this time the condensed liquid is prevented from returning to the flask. This soon results in the almost complete removal of the solvent, and the flask is then taken from the apparatus and placed on a hot plate.

The last traces of solvent are removed by means of a gentle air current over the flask top, and the oil is left in the flask. The flask and oil are then cooled to room temperature and weighed. The new weight, minus the original weight of the flask, is the amount of oil extracted. This weight, divided by the original meal weight and multiplied by 100 gives the percentage oil in the material from which the sample was taken.

Although there is an undoubted similarity between the above extraction and commercial practice, there are various reasons why this method cannot be applied directly to commercial practice. The differences will become clearer with succeeding

chapters, but it would be helpful to refer to certain of these at this stage.

The solvent, passing on its downward journey to the meal carton is essentially pure, and however small the quantity of oil in the solvent leaving the meal, the whole of the solvent must be evaporated and condensed before it can again pass through the meal. The actual amount of distillation will depend upon the amount of heat applied to the flask, but it will be obvious that a very large amount of heat has been used to extract oil from a very small amount of meal. Commercial practice is not as severe as this, and all of the oil is not removed. Moreover, all solvent plus oil is not immediately distilled.

The first washing or flooding of the meal usually takes place with solvent containing oil from previous washes, and only the final wash is carried out with pure solvent. In this way, a considerable economy is effected.

The time cycle for extraction is considerably under four hours, but actual times depend upon many features which are not relevant at this stage.

Batch Extraction

Commercial extraction of oil seeds follows two broad lines :

(1) Batch extraction.

(2) Continuous extraction.

As in many other branches of the seed crushing industry, there are many variations in actual practice, both in the application of the batch principle and in continuous extraction. The student will realize, therefore, that in dealing with these subjects, the broadest possible view will be taken, and the plant shown in the diagram cannot be regarded as standard, since no standard exists. The sequence shown, however, is sufficiently typical to be a useful basis for study.

The object of first studying a flow or sequence chart in this instance is that by so doing, a general overall idea of the process will first be envisaged. This can then be followed up by more detailed study of the various features embodied.

Plant Sequence

The meal container, commonly known as the "pot," is situated on the extreme right of Fig. 34. In practice, this plant operates ten pots, but since each pot is exactly similar to its neighbour, the inclusion of the remaining nine in the diagram would only serve to confuse the reader.

The pots are usually placed in a straight line and are charged by means of hoppers, which are in turn fed by means of scraper or other type conveyors. The seed meal under process is not

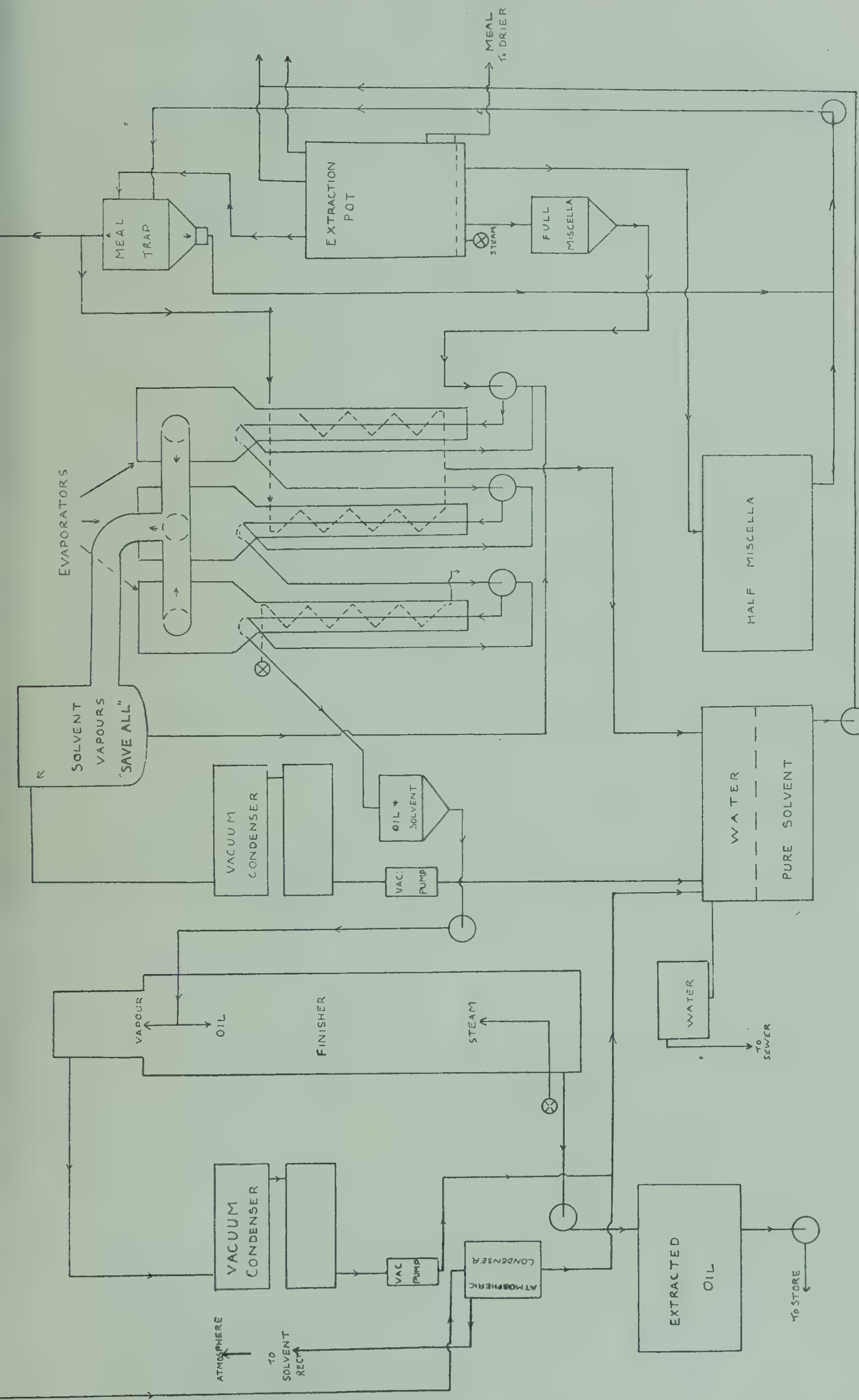


Fig. 34 **Diagram showing plant sequence of batch extraction**

dissimilar from that used for other processes previously dealt with. This means that unless the initial oil content of the seed is comparatively low, it is more than likely that the bulk of the oil has already been removed and that the supply to the pots is part expelled cake meal containing between 18 and 25 per cent. oil.

The first application of solvent is known as flooding, and pure solvent is not used for this purpose. Part used solvent from the previous wash is held in the half miscella tank for this purpose. After the meal has been thoroughly drenched with solvent, a drain cock is opened and the oily liquor or full miscella is allowed to drain away to the full miscella tank. The next process commences the separation of solvent and oil. For this purpose, a special type of evaporator is used.

The continuous evaporator shown in the diagram consists of three units in series. The liquor is pumped through the tubes of the first leg and back to the pump, via a circulating pipe. In addition, succeeding supplies are passed to the secondary leg, and so on to the third leg. The heating agent surrounding the first two sets of tubes consists of solvent and steam vapours from the pots. The heat exchange is twofold.

The solvent in the tubes is vaporized and, on reaching the large chamber at the top, is sucked away for subsequent condensation. The third leg of the evaporator is steam heated, and here evaporation of the solvent is intensified. The oil, finally emerging from the third leg of the evaporator, now contains little solvent and this concentration is pumped to the top of a Kestner finisher. The finisher is so built that the oil and solvent are spread over the maximum area while travelling to the lower section. Steam is injected near the base of the finisher, and on passing upwards through the liquor, the remaining traces of solvent are vaporized and sucked out at the top by means of a vacuum pump via a condenser. The condensate is then allowed to drain into the pure solvent supply tank. Meanwhile, the oil reaches the base chamber of the finisher and is passed out to the store tank.

The meal in the pot is then given a wash with pure solvent, but since the oil content of the meal has already been lowered considerably the solvent is still fit for further use.

The slightly oily solvent, on passing from the pot, is pumped to the half miscella tank. This tank supplies the part oily liquor for the initial flooding of the second pot and succeeding pots. The meal in the pot has now been reduced to a very low oil content indeed, but a good deal of solvent is still retained. To

drive off the remaining solvent, steam is injected at the base of the pot. The stirrers are set in motion at this stage, and this assists in vaporizing the solvent.

The steam and solvent vapours pass out at the top and may pass to either or both of the pipes shown in the chart. The first is to the evaporator body as stated previously; the second vapour mixture passes to the atmospheric condenser for conversion to the original liquid state. On reverting to the liquid state, the water and solvent separate, the solvent dropping to the bottom of the supply tank as its density is much greater than that of the water. The meal trap set in the steam and solvent line is flushed with half miscella and the mealy liquor is returned to the pots.

Meanwhile, the solvent vapours drawn from the heads of the evaporators are passed via a "save all" to a set of condensers and vacuum pump, and thence to the pure solvent tank.

The large compartment called the "save all" is used to trap any entrained oil and return it to the pumping system on the evaporators. Surplus air from the pot vapours is allowed to escape from the atmospheric condensers, and to ensure recovery of any solvent still in vapour form, it is passed through a bed of pure carbon. The carbon readily absorbs the solvent which is recovered by steaming at intervals. The cleansed air is then allowed to pass into the atmosphere.

Function of the Pot

Having already dealt with the plant layout and sequence of the process, and in order to follow up the general description with more detail, it is necessary that the complete process be split into sections. The sections in their order are:

(1) Preparation of seed.

(2) Solvent treatment, extraction pot.

(3) Removal of solvent from meal pot.

(4) Separation of solvent and oil.

(5) Drying of meal.

PREPARATION OF SEED.

Here, much depends upon the particular type of seed under treatment. In the case of a high oil content seed which has been treated by expellers in order to remove a good deal of the oil, the cooking for expelling is influenced by the requirements of the extraction process.

The cooking processes require the use of much more "live"

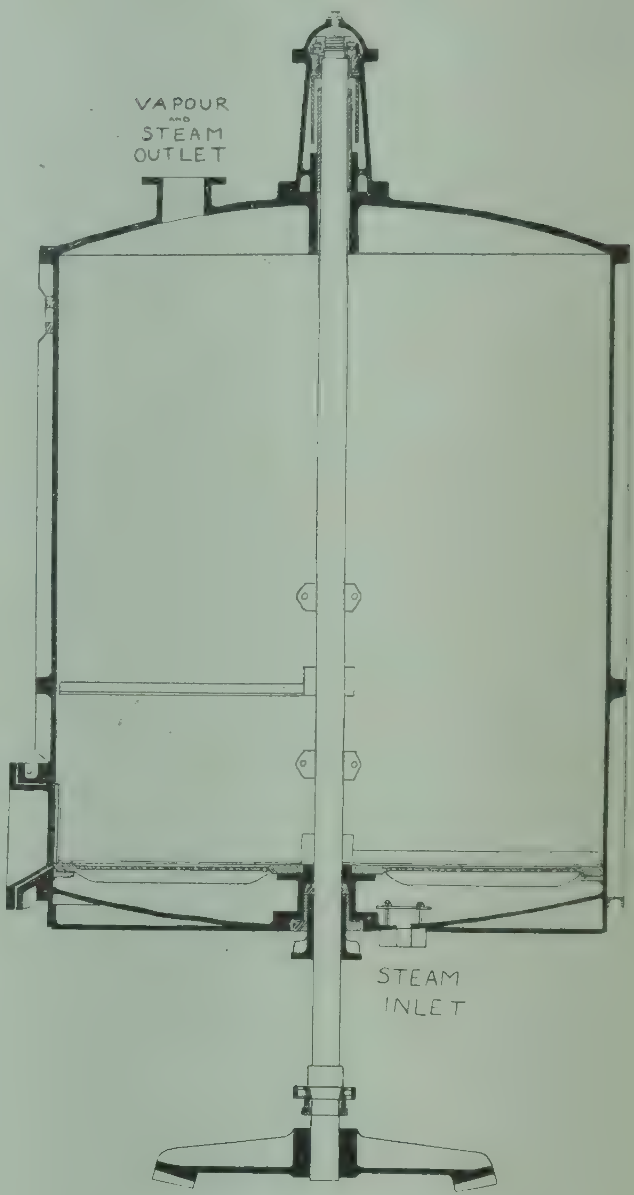


Fig. 35 **Sectional view of Extraction Pot.**

or direct steam than that for straight expelling. This is particularly so in the case of groundnuts. The expelled cake, therefore, contains a much higher moisture content, and there is a definite reason for this. One of the greatest problems that has confronted the extraction plant operator is that of drainage. The draining efficiency of a meal is largely a function of particle size of rolled material, and this is controlled by the cooking as stated above and Anglo-American rolling.

Wet or live steam cooking tends to reduce the production of fine meal and the resultant rolled product is of a thin flaky consistency. On the other hand, coarse rolling also reduces the quantity of fine meal produced, but if the oil cells in the meal are not efficiently ruptured, the solvent cannot penetrate the interior of the particles and the efficiency of the extraction process is thereby seriously impaired.

It would appear, therefore, that the ideal subject for the extraction process is meal which is well rolled but of a flaky rather than mealy consistency. The pre-treated seed or cake is usually taken from the Anglo-American rolling plant by means of scraper or screw conveyors. The conveyors run above a line of hoppers and a controlled feed outlet is mounted over the centre of each hopper. By this means, a fixed charge of feed can be run into each hopper. Each hopper surmounts an extraction pot, and the outlet from the hoppers can be quickly

connected to the pot for charging purposes by means of a fabric chute.

EXTRACTION POT.

The sectional diagram (Fig. 35) shows a typical design of extraction pot. The internal diameter is 6 ft. 6 ins. and the height of the chamber is 8 ft. The meal inlet is not shown in this particular view, but consists of a flanged orifice of 9 ins. diameter. The smaller flanged opening on the left of the central shaft provides an outlet for solvent vapour steam and displaced air. The solvent inlet is on the side of the pot near the top. The extracted meal exit door is at the lower left hand corner and, when closed, is gas tight as well as liquid tight. The four single stirrers, or agitators, are used in certain phases only of the extraction operation.

The main or meal chamber is divided from the smaller base chamber by means of a special type of screen, which latter is usually constructed in three layers. The bottom layer is of cast iron or steel segments. The perforations are $\frac{3}{4}$ inch diameter at the lower face and of slightly less diameter at the upper face. The upper screen is of mild steel sheet with much smaller perforations. The real screening agent is the inner layer and this differs a good deal with different designs. In some cases, coconut matting is used, while in other cases, a very fine copper screen may be fitted.

The miscella (oil and solvent) exit is at the lowest point in the pot base and adjacent to the steam inlet.

OPERATION FOR TREATMENT USING EXPELLED GROUNDNUT CAKE WITH ABOUT 20 PER CENT. OIL.

The phases in the operation of the extraction pot are :

(a) Charging with meal.
(b) Flooding with solvent, half miscella.
(c) Draining.
(d) Washing with pure solvent.
(e) Draining.
(f) Steaming off.
(g) Discharge of meal.

Since most plants include a number of pots, it will be obvious that the phases shown are being carried out simultaneously, but each on a different pot. For convenience and clarity, one pot cycle will be described.

(a) A measured charge of meal is fed into the pot from the hopper. The meal inlet pipe sleeve is disconnected and a balanced door is closed over the meal inlet orifice. The door is a snug fit, and when bolted tightly down is gas tight. This is necessary in order to prevent vapours escaping to the atmosphere during the extraction or steaming phases.

(b) A cock on the half miscella line is then opened. The meal is flooded with half miscella to a point a little above the meal level and the half miscella inlet cock closed. The height of the solvent can be seen readily on the sight glass on the side of pot.

(c) After a short period, the oil solvent exit is opened to the full miscella line for treatment on the evaporating installation.

(d) On completion of the drainage period, the drain cock is turned over to the half miscella drain line and pure solvent is admitted from a second line over the pots from the pure solvent tank. The outlet or drain under the pot is now opened to the half miscella tank for re-use on successive pots. The oil content of the meal at this stage is sufficiently low to produce only a weak solution of oil and solvent. By re-using the half miscella for the flooding operation, an economy is effected in the amount of evaporation necessary.

(e) Another drainage period is necessary after closing the cock on the pure solvent inlet line. On the completion of the draining period, there is still a fair amount of solvent in the meal, but the total amount of oil present is now very low indeed.

(f) The drain cock is now closed and the steam inlet cock opened. The pressure of the steam (usually 50 lb. per square inch) raises the temperature inside the pot and the solvent commences to evaporate. To aid the searching power of the steam, the agitators are set in motion. The continuous jostle of the meal particles under agitation ensures that the steam reaches every part of the pot. The steaming process continues until no trace of solvent vapour is present. This can be detected by passing the steam to a small condenser, where the presence of solvent is shown by the tell-tale division between water and solvent. The vapours pass out at the opening in the top of the pot shown in the diagram and their subsequent treatment will be described later.

On completion of the steaming operation, the steam is shut off and the vapour escape closed. The meal inlet door is then opened to release any residual steam pressure and the meal outlet door is then opened. The damp meal then passes to driers for further treatment.

CHAPTER XIV.

SOLVENT RECOVERY AND OIL SEPARATION

Solvent mixtures passing from the pot fall into three groups :

(1) Full miscella, or very oily solvent solution.
(2) Half miscella, or slightly oily solvent solution.
(3) Steam and solvent vapours.

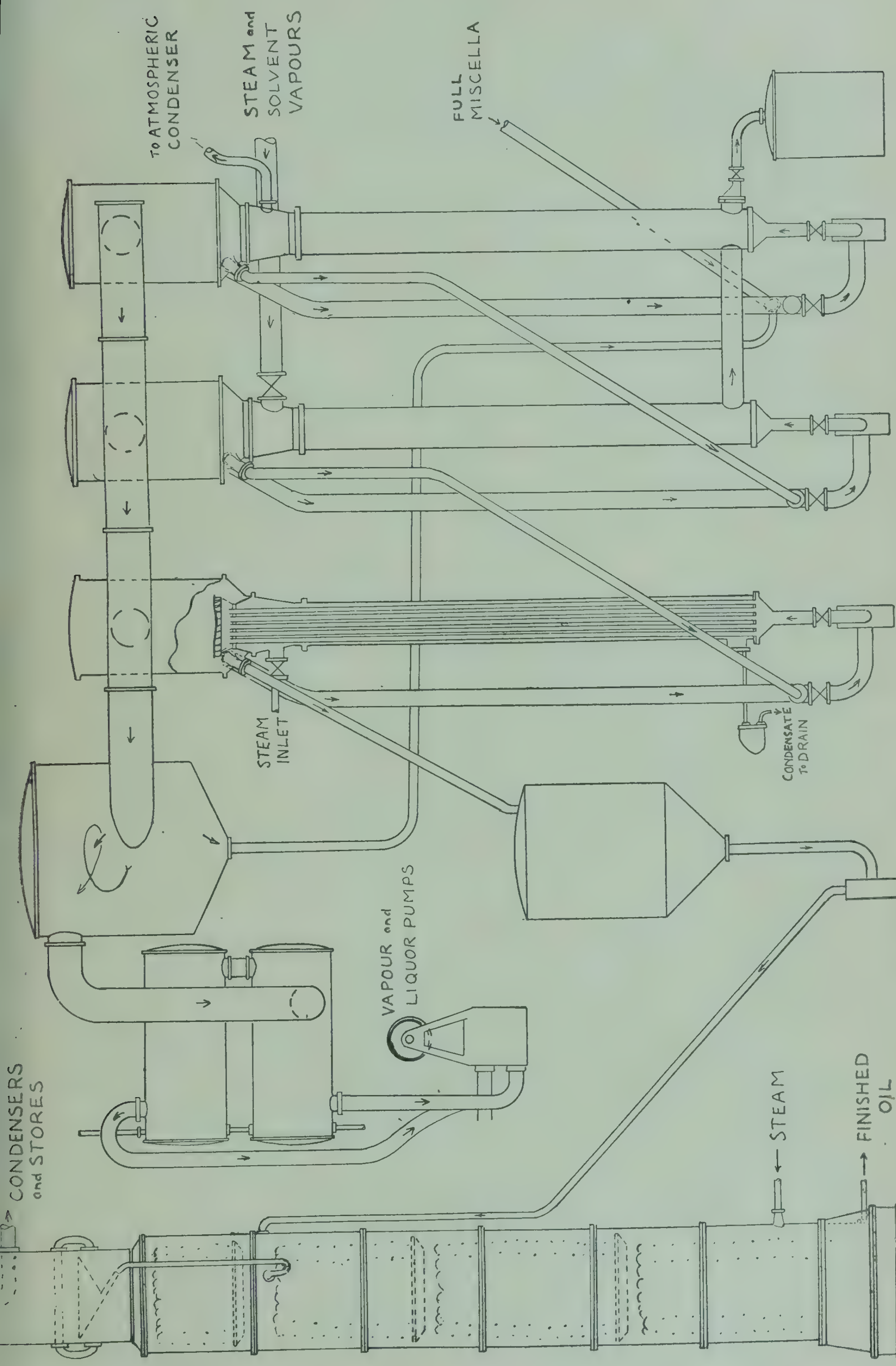


Fig. 36 Diagram of Solvent Recovery Section of Oil Extraction Plant

It is not economical to distil solvent from weak solutions and, therefore, the half miscella is used again for a first flood on succeeding pots. The full miscella, which has been obtained by flooding the pot with half miscella, may contain 20 or more per cent. oil, and this is considered an economic medium for solvent distillation. The steam and solvent vapours, after removal of any entrained meal, are suitable for direct condensation.

Since the condensation of steam and solvent requires a cooling agency, and the evaporation of solvent from the full miscella requires a heating agency, a mutual heat transfer system has been designed to assist in these two operations. The heat transfer equipment as described is not sufficient of itself, and steam has finally to be used in the attainment of total evaporation of solvent from the oil. Similarly, total condensation of the pot vapours requires the use of atmospheric condensers in the latter stages of solvent recovery.

FULL MISCELLA.

By means of the Fig. 36, the path and treatment of the full miscella can be followed.

On draining from the extraction pot, the full miscella eventually reaches the inlet pipe to the pumps under the first leg of the continuous evaporation unit. The evaporation unit may consist of 1, 2, 3, or 4 separate evaporators, linked as shown on the drawing. The final or third leg only is shown in section, but the first and second are identical in construction. At this stage, a description of the principles upon which this evaporator works is necessary.

Each " effect " of the continuous evaporator consists of two main sections. The lower section, known as the calandria, constitutes the heat transfer unit; the tubular column, 23 ft. long, contains 19 tubes of 2 ins. diameter. The tubes are secured to a head plate at the top and a similar plate at the bottom. The space around the tubes is enclosed by the plates which carry the tubes, and it is this space into which flows the steam and solvent vapour in the case of the second leg. The spaces in the second and first leg are connected by a horizontal pipe at the base, and this pipe has a two-fold purpose. Some of the vapours pass via this pipe and into the first leg, while condensate from the second leg joins that of the first leg via the same pipe.

In the event of any vapours failing to be condensed, an escape pipe is fitted to the top of the first leg which leads to an atmospheric condenser.

The condensate from both pathways eventually reaches the pure solvent tank; the solvent, in this case trichlorethylene, being heavier, falls to the lower part of the tank while the water joins that which is already in the tank.

The same space in the calandria of the third separator is

supplied with steam, the inlet and outlet being shown clearly on the drawing.

The full miscella enters the lower part of the tubes via a vertical pipe on the left of the first calandria and a centrifugal pump. The pump is not essential to the evaporation operation, but the action inside the tubes is somewhat different when working in this manner.

The evaporator can be described as that of the "climbing film." The liquor, in this case the full miscella, on reaching the tube entrances is heated by the means already described. Evaporation commences to take place at once and the vapours rise up the centre of the tubes in search of regions of lower pressure. In doing this, the vapours induce a thin film of liquor to climb up the inner surface of the tubes. Since evaporation of the liquid tends to be superficial, it will be seen that an enormous increase of surface area is obtained and evaporation is continually taking place throughout the lengths of the tubes. On reaching the top of the tubes, a baffle plate is met. The baffle plate is fitted with a series of curved radial vanes.

The vanes induce a circular motion to the liquor, which is by-passed back to the pumps by means of the vertical pipe described previously.

When the supply of liquor exceeds the circulatory capacity of the first leg of the evaporator, a slightly higher outlet pipe is reached and the liquor flows out by means of this pipe to the inlet pump line of the second leg, and so on to the third leg.

On reaching the escape pipe of the third leg, the greater part of the solvent has already been evaporated and liquor flows to an intermediate container en route for the finisher.

Here, it would be advisable to leave the liquor and return to the evaporator once again.

The top tube plates and baffle plate are housed in an expansion chamber, or separator, surmounting the calandria. The three expansion chambers are linked by means of a large duct to a vessel which has been designed to eliminate any oil which may have become entrained in the vapour. The vessel is called a "save all," and its large size ensures a sufficient velocity drop to accomplish this.

The spiral motion induced by leading in the vapours at the side causes the oil to fall with any condensate from the "save all," via the pipe at the bottom and back into the circulating liquor in the first evaporator. By this means, only pure vapour leaves the vessel via the top outlet duct which is connected to the lower of two vacuum condensers. The vacuum condensers are so called because they are exhausted by means of a vacuum pump as well as a liquor pump. The liquor passes through the liquor pump and thence to the pure solvent store.

The vapours which fail to condense inside the cooling chamber are sucked out by the vacuum pump, together with any air which may be present in the system, and passed to an atmospheric condenser. The liquor from the atmospheric condenser passes to the pure store tank, and air, plus solvent traces, are allowed to escape from the top of the condenser for further treatment.

The vapour pump is capable of maintaining a vacuum equal to about 2 lb. per square inch absolute. This low pressure is common to all parts of the system between the pump and the evaporator heads. Thus, the upward movement of the liquor and vapour in the climbing film tubes is assisted by the rarified pressure in the upper part of the evaporator.

Since evaporation of a liquid takes place when the vapour pressure in the liquid exceeds the pressure exerted against the liquor surface, it will be seen that the rarified atmosphere induced in the tubes accelerates evaporation of the solvent in the film on the tubes.

FINISHER.

The full miscella, or oily solvent, on leaving the extraction pot may contain as much as 15 per cent. oil and 85 per cent. solvent. As the miscella passes through the evaporators, the oil/solvent ratio is constantly changing, owing to the rapid evaporation of solvent. On passing from the evaporators to the intermediate store tank, the oil/solvent solution is probably approaching 90 per cent. oil and 10 per cent. solvent. The remaining solvent is effectively removed by means of the finisher.

The finisher is a tower-like structure, over 60 ft. high. At intervals in the main body, four steel lath trays cover the entire cross-section. Each tray is loaded with many thousands of Lessing rings to within a foot or so of the tray above. The rings are made of porcelain, 3 ins. diameter × 3 ins. deep, with a central bridging piece.

Immediately below the lowest tray, a pipe carries steam to the centre point of the cross-section, and the outlet, which points vertically upward, is surmounted by a small cowl to assist in distributing the flow.

The thimble-like chamber at the top of the finisher is divided into two compartments by means of a drain tray, and upward travelling vapours are forced to make use of the by-pass pipes on each side of the chamber.

The by-pass pipes do not project upwards in a true vertical direction, but at an angle of 45 degrees. The pipes describe opposing angles, the effect of which is to produce a rotary motion of the vapour in the finisher head. A pump below the intermediate container forces the oily liquor to a point just below the topmost tray.

The liquor is sprayed into the body of the finisher and it flows downward via the Lessing rings. On meeting the steam which is rising upwards, the solvent is gradually evaporated. The gaseous solvent travels upwards and via one by-pass spout into the topmost chamber and is sucked away to a condenser unit by means of a vacuum pump. The condenser unit is similar to that shown for the treatment of vapour from the " save all."

In the event of entrained oil reaching the upper chamber of the finisher, it is received by the dividing drain tray and by-passed back into the finisher main section. The oil, which is flowing downwards through the banks of lessing rings, reaches the base of the finisher perfectly free of traces of solvent and is led off to the store tank by means of a pump.

CHAPTER XV.

MEAL DRYERS AND COOLERS

After extraction of oil, the meal residue is treated to a thorough steaming, the purpose of which has already been described. When traces of solvent are no longer present in the vapour passing from the pot, the steaming is discontinued and the meal door opened. The meal is very wet, due to inevitable condensation during the steaming process. The moisture content of the original meal may have been in the region of 6 to 10 per cent. The removal of, say, 18 or 19 per cent. oil would have the effect of increasing the moisture content of the meal to as much as 12.5 per cent. if no water is added or removed. On leaving the pot, the final moisture content of the meal may be as high as 30 per cent., and for a variety of reasons this must be reduced. Firstly, the keeping quality of the meal is seriously impaired by excessive moisture and, secondly, water over and above the natural amount does not increase the value of the product.

For the reasons given, it is desirable to reduce the moisture content to an amount which will obviate any loss in weight due to processing, and which will also reduce to a minimum those changes in weight which occur almost daily when the moisture is artificially high or low. Excessive moisture is removed by means of a drying machine.

There are many types of dryer on the market, each with definite advantages. All drying machines within the range of the present subject have two features in common :

(1) Application of heat;
(2) Forced draught for vapour removal.

The accompanying illustration (Fig. 37) shows a view of a

type of dryer as used on a large extraction unit. The drying chamber consists of a large rectilinear housing. Three sets of specially designed horizontal scraper conveyors turn slowly in the main body, the scrapers being slung on cross beams set at intervals on a twin chain system.

The method of slinging the scrapers on the shaft is shown in Fig. 38. Each shaft carries eight scrapers of 2½ ins. width, and each bed traversed by the scrapers is composed of a series of steam heated plates. The obtruding lip on the top plate of

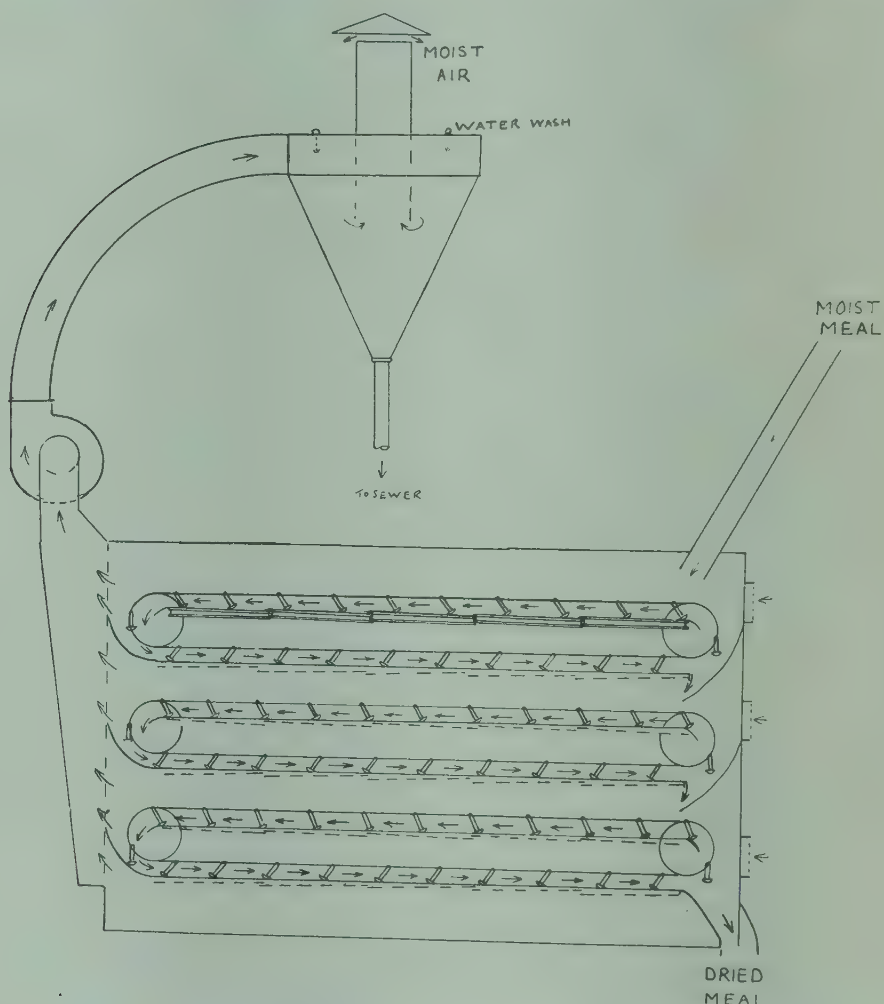


Fig. 37. **View of Extract Meal Cooler.**

each succeeding chamber rests on the upper surface of that following, the lip being rounded off to maintain a reasonable continuity of surface.

On reaching the end of the first heated surface, the thin layer of meal falls on to a guide plate which just clears the scrapers, and as the scrapers change direction, the meal is taken from left to right on the second heating face. At the end of the second horizontal run, another guide plate ensures that the meal falls on to the third heating surface, where the first cycle is

repeated. The third conveyor is identical. The diagram shows the steam chambers of the first heating surface, the others, not shown completely, are similar.

At the conclusion of the third cycle, the meal is ejected by means of an air seal feed roll.

For convenience, the drawing shows the whole of the side of the chamber removed. The end of the chamber is fitted at

Fig. 38 Method of Slinging Scrapers on Shafts.

intervals with doors made of perforated steel sheet of $\frac{3}{8}$ in. holes. At the other end of the chamber, an exit shaft projects to a fan which exhausts to a cyclone above. There is a little dust present in the air stream, and this may be removed by washing the air with water inside the cyclone. The free air is then ejected to atmosphere, preferably above the roof level.

The capacity of the dryer is, of course, a function of the size of the heating faces. A large machine, with six heating surfaces each 50 ft. × 6 ft., will dry about 10 tons of meal per hour from 30 per cent. to 12.5 per cent. moisture.

The steam pressure applied to the chambers is 50 lb. per square inch, and the temperature of the meal leaving the dryer is about 200 degs. F. By raising the steam pressures, the capacity can be increased, but this results in increased temperature of the dried meal. Excessive temperatures tend to toast the meal and in most cases this is not desirable.

The depth of the meal on the heating surface depends upon the speed of the scraper conveyor, as well as upon the rate of feed, and an ideal depth of meal is about 2 ins. To obtain this, the conveyor speed should be about 60 ft. per minute.

The warm meal passing from the dryer must now be cooled to a temperature which facilitates storage. If this is not carried out, the moisture remaining in the meal will continue to evaporate, but on arriving into the atmosphere will be condensed immediately. The effect of this is to produce high moisture contents in the outer layer of meal whether in a bag or silo. The high moisture content, even of portions of the meal, results in bacterial action which accelerates decomposition and makes storage impossible.

Meal coolers are not dissimilar from dryers in general appearance. The main difference is that heat is not applied to the conveyor surface which is simply a plain sheet of steel. The cooling air, drawn from atmosphere, travels from one end of the cooler to the other in such a way that a stream of air passes along each bed close to the surface of the meal. The movement of the air is actuated by both an inlet and outlet fan at opposite ends of the machine. The air passed through the fan is now more likely to be dust laden and, for this reason, is dissipated through fabric sleeves of the type shown in the chapter on cake cooling.

Points to be borne in mind are:

(1) The meal should attain only that temperature which is necessary to evaporate the correct quantity of moisture.
(2) The warm meal must be cooled immediately after drying.

CHAPTER XVI.

CARBON TRAP FOR SOLVENT

The carbon trap for recovery of solvent from air passing through the plant has been mentioned briefly in an earlier chapter. Many extraction units are not fitted with carbon adsorbers, but rely for solvent recovery on passing the waste air through a deep hopper of meal which has been prepared for extraction. This method is fairly effective, but it is by no means as efficient as that of the carbon traps. To be thoroughly effective, a preliminary scrubbing of the solvent-laden air with a caustic solution is necessary, because certain sulphur bodies produced in the extraction process are entrained with the solvent vapour, and these sulphur compounds destroy the ability of the carbon to adsorb the solvent and, accordingly, must be removed.

CARBON ADSORBER.

Fig. 39 shows the method of carrying out this operation. The solvent-laden air from the atmospheric condensers enters the vertical tower at the lower section and travels upward. The lower chamber of the tower acts as a reservoir for a solution of caustic, which is pumped to a point near the top of the tower. Here, the solution meets a series of wooden frames which spread and slow down the flow. The rising vapours are scrubbed by the counter flowing solution, and the sulphur compounds are washed out and passed with the solution to the reservoir. The circulation of liquor is maintained until a fresh charge is found to be necessary. This condition can be ascertained by testing the vapours leaving the scrubbing tower

for the presence of sulphur compounds. A piece of lead acetate paper is allowed to contact the vapours, and in the event of certain sulphur compounds leaving the tower with the vapours, the paper turns black. The old charge is then passed to the sewer via the cock at the base of the container and a fresh charge is pumped in.

The rising vapours filter through a screen of glass wool before leaving the tower. This prevents entrainment of caustic and ensures that only pure solvent and air will pass to the

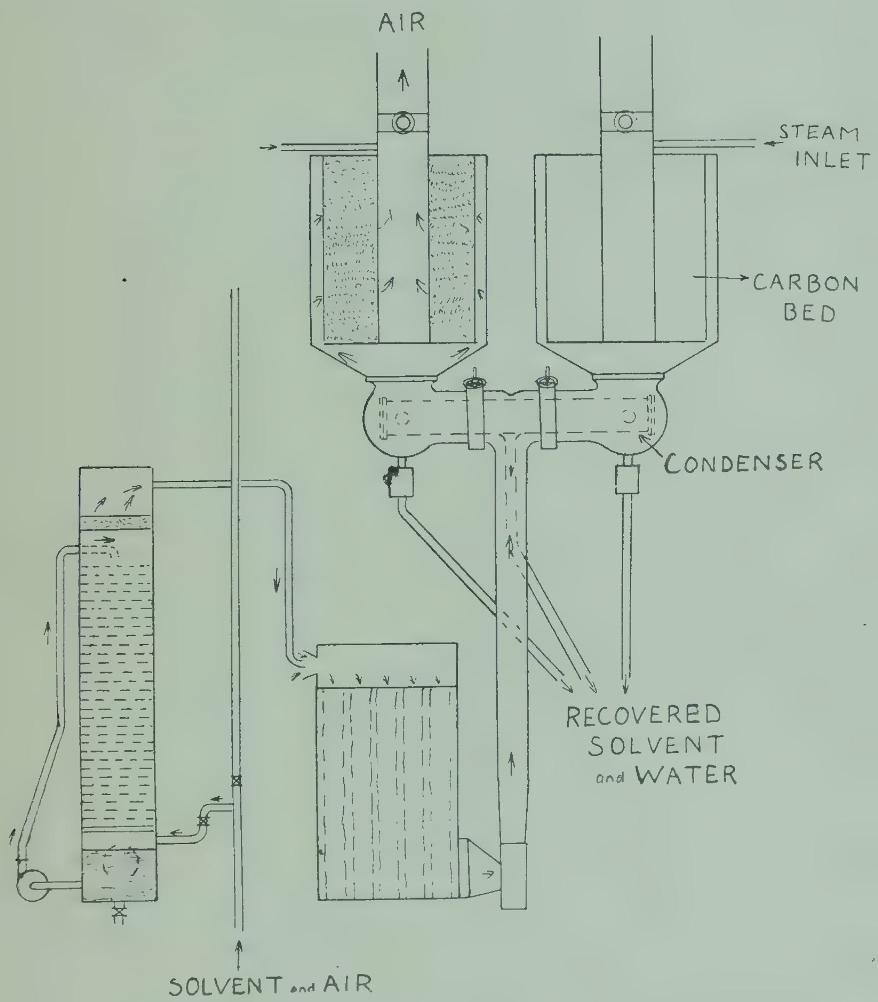


Fig. 39

recovery section. The concentration of vapour is now diluted by the addition of air, which has the effect of distributing the vapours evenly through the carbon.

The method of adding the air is shown on the diagram. The air and vapour from the tower enter a funnel-shaped orifice on the side of a fabric filter installation. The size of the orifice is large enough to allow a considerable quantity of air from the atmosphere to enter also. The inducement is provided by a fan at the lower right-hand corner of the installation. The sleeves

are totally enclosed, and as the fan withdraws the air surrounding the sleeves, the vapour and air in the top chamber are sucked in to replace it. Any solid impurities, such as dust, are trapped in the sleeves and the pure air and vapour pass through the fan to one of the carbon traps.

The vapours travel via the bulbous container below the bed and reach a space outside the carbon. The vertical outlet is sealed at the base and the gases are forced to pass through the carbon in order to escape to the atmosphere. The carbon adsorbers are shown in duplicate and are worked alternately.

After working for about three hours, the second bed is put into use by opening the valve in the pipe leading to the bed. The first bed is then sealed off by means of the valve on the opposite side of the T-joint. The air escape valve above the carbon bed is closed and steam is admitted just below this valve. By means of the steam, the solvent is driven off the carbon and passed, via the bulbous lower chamber, to a condenser immediately behind. The condensate, which is a mixture of water and solvent, is then passed to a separating tank, from which the solvent is returned to store and the water to a waste pipe. Any condensate which is formed in the lower chamber is ejected by means of the drain pipe below. The steaming leaves the carbon in a wet state and the extra air intake, referred to previously, assists in drying out the moisture.

In order to make this more efficient the vapours are heated to about 90 degs. F. at a point immediately before entering the fan.

Solvent Displacement by Water

Another feature of the extraction process which has been briefly touched upon, is the method of passing solvent to and from the store tank. It is none the less an important part of the plant and must function correctly if smooth performance is desired.

The chief reason for using the solvent displacement by water system is the preservation of solvent vaporization in the store tank.

If the pure solvent could be sent to the extraction plant, distilled and returned to the store tank in an unvarying stream, no special equipment of the type to be described would be necessary. Although the return of freshly distilled solvent is fairly steady and continuous, the demand for fresh solvent to complete the final wash is by no means continuous. The demand takes place at fairly regular intervals, when the time schedule can be exactly carried out, but there are liable to be heavy demands at certain periods and little or no demand at other periods. This is particularly so where a small number of pots is involved.

The store tank pressure should be as steady and unvarying as possible. To obtain this steadiness a heavy demand for solvent, which is in excess of the return supply, must be replaced by water and in circumstances where the demand has ceased, and distilled solvent must be returned to the tank, a corresponding amount of water must be displaced. This can best be explained by referring to Fig. 40.

The pressure head in the store tank depends upon the height of the water column. This may be, say, 10 feet, which is approximately 5 lb. per square inch. When solvent is withdrawn

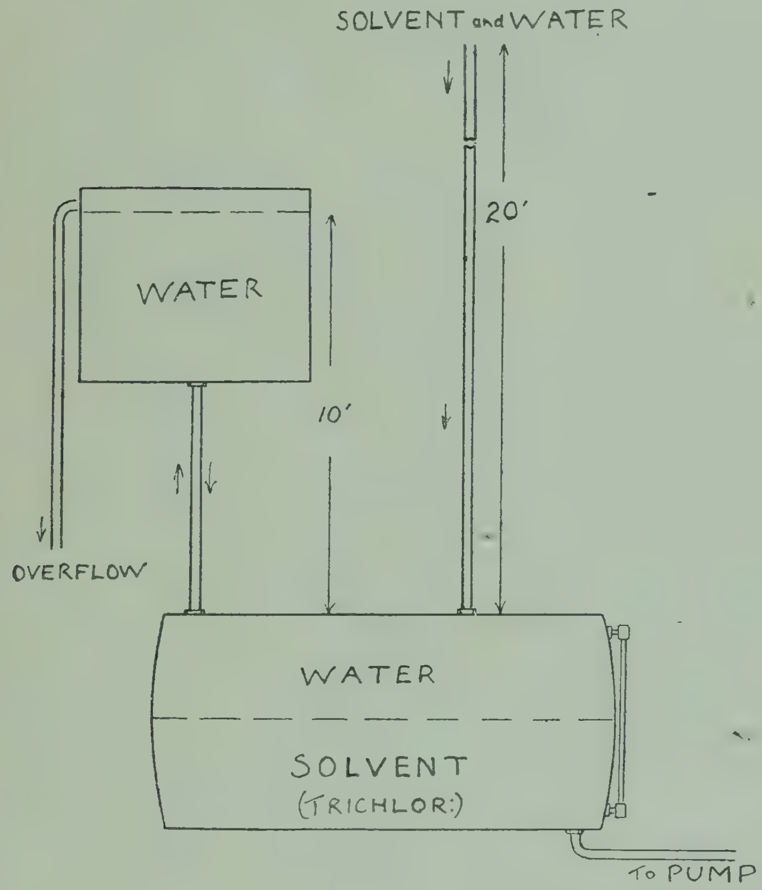


Fig. 40.

from the tank, water flows in to replace it. The water supply tank is large enough to accommodate the maximum demand of solvent for the washing operation. It has been stated previously that the return of distilled solvent to the store tank is fairly continuous, and if, therefore, the demand on the tank has ceased, the condition is likely to arise when solvent is attempting to enter a tank which is already full. This is made possible by the relative positions of the plant features. The solvent store tank is situated at the lowest possible level and the water tank level is only 10 feet above this.

The pure solvent, plus water, is returning from the condensers, which are situated many feet above the water tank, and the head is increased according to this position.

In addition, the specific gravity of trichlorethylene being 1.47, the pressure head for the same height would, therefore, be increased in the ratio 1 :1.47. Should the solvent "return" commence at, say, 20 feet above the store tank, the pressure exerted on the tank would be :

Pressure exerted by water at 20 ft. = 10 lb. per sq. in.

$$\text{Pressure exerted by trichlorethylene at 20 ft.} = \frac{10 \times 1.47}{1}$$

$$= 14.7 \text{ lb. per sq. in.}$$

Since the return liquor is a mixture of solvent and water, the "head" will be somewhere between 10 and 14.7 lb.

It will be seen, therefore, that the returning liquor is capable of pushing the water back into the water supply tank. If the quantity of returning liquor is great enough, the level in the tank will eventually reach the outlet pipe to waste. Should this happen, it may be necessary to make up this loss later by once more filling the water tank by means of a tap or, in some cases, a ball valve installation.

CHAPTER XVII.

A GENERAL SURVEY OF OIL REFINING

Since these remarks are intended to follow a course which has been mainly concerned with the crushing and extraction of vegetable oils it may be advisable to point out that a much larger variety of materials are available to the oil refiner and the methods he uses can in most cases be applied equally well, whether the oil is of vegetable, animal or marine origin.

The following list is given as an indication of the different types of oils and fats which may be met with, bearing in mind that it is by no means a complete list :

Vegetable.	Animal.	Marine.
Olive	Pig fat (lard)	Whale
Groundnut	Beef tallow	Seal
Cottonseed	Mutton tallow	Herring
Palm	Milk fats (butter)	Sardine
Palm Kernel	Wool fat	Cod-liver
Copra	Neatsfoot oil	Halibut-liver
Sunflower		
Linseed		
Tung		
Soya		

Oil is a fundamental factor in the composition of all animals and plants, and since each species produces its own characteristic type of oil, it is obvious that there are hundreds of different types of oil in existence, so before proceeding any further with the various methods and stages in refining, it may be more helpful if we consider briefly something of the chemistry of these oils in order that we may better undestand the relationship between them, and also help in following the refining processes.

Oils consist mainly of mixtures of substances called Triglycerides, that is to say, they can be built up from or broken up into glycerine and fatty acids.

We are familiar with glycerine as a colourless, viscous liquid; one of its properties is that it can combine with or react with fatty acids in the proportion of one part, or one molecule, of glycerine with three parts, or three molecules, of fatty acids. Thus, imaging a glycerine molecule to be represented by the letter E, then each of the three arms may unite with a fatty acid molecule, forming a compound known as a triglyceride.

We must now consider these fatty acids. They may be regarded as members of two or three closely related families or groups of substances. About fifty different fatty acids are found to occur in the various fats, the chief ones being members of a family of which the lowest or smallest member is formic acid, then acetic acid (the acid of vinegar) and so up the series, each higher member differing by the addition of one atom of carbon and two atoms of hydrogen, forming a longer chain.

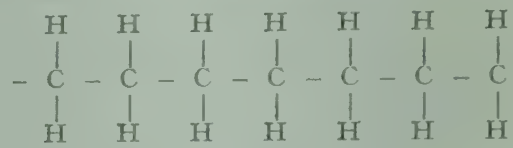
This may readily be shown by the use of chemical symbols and formulæ

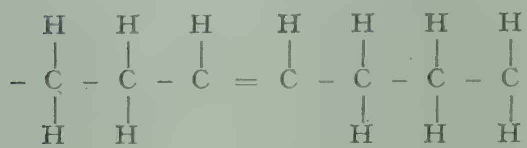
Acid	Number of Carbon Atoms	Formula
Formic	1	$H.COOH$
Acetic	2	CH_3COOH
Propionic	3	CH_3CH_2COOH
Butyric	4	$CH_3CH_2CH_2COOH$
.	.	.
.	.	.
.	.	.
Lauric	12	$CH_3(CH_2)_{10}COOH$
Palmitic	16	$CH_3(CH_2)_{14}COOH$
Stearic	18	$CH_3(CH_2)_{16}COOH$

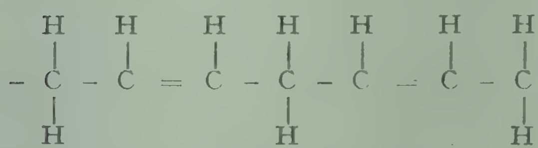
The acids in this series are all " saturated " acids, that is to say, if we imagine the carbon atoms to be linked together by means of bonds, four of which are inherent in each carbon atom, then there is only one link between the successive carbon atoms in the chain.

Other series of acids are known in which the linking between some of the carbon atoms is different and may be pictured by imagining two of the links being used between two carbon atoms, this often being referred to as a " double-bond." Again, more

than one double-bond may occur, possibly up to four or six in one acid chain.


– SATURATED CHAIN


– CHAIN WITH ONE DOUBLE-BOND


– CHAIN WITH TWO DOUBLE-BONDS

The question of what proportion of saturated acids an oil contains is important, because some of the chief properties of the oils are dependent upon this point. Broadly speaking, the more double-bonds an oil contains, or the more unsaturated it is, the lower becomes its melting point and the nearer it approaches to the " drying-oil " type of oil, such as linseed. It might also be pointed out here that when an oil is " hardened " i.e., hydrogenated, it is the double-bonds which take on the hydrogen and thus become saturated.

It is apparent, therefore, that a very large number of different triglycerides are theoretically possible, since a glyceride may contain three acids which are all the same, or it may contain two of one type and one of another, or the three may all be different; further differences occur according to the positions taken up on the different arms of the E of the glycerine molecule.

In any one particular fat, therefore, it depends largely upon the number and the relative proportions of different fatty acids which exist in its make-up as to how many different triglycerides we might expect to find in that fat.

It is very unusual to find a fat which has less than four different fatty acids, generally between six and twelve different types occur; even so, it is readily seen that a considerable number of variations in glyceride composition is possible, and since the chemical and physical properties of these different triglycerides are so very similar in many cases, it has not been possible to say with any degree of accuracy just what is the composition of any particular oil or fat. In recent years, however, rapid advances have been and are being made in methods of analysis, and for several of the more common oils, a reasonably clear picture of their composition is now available.

Although the food industry is by far the largest consumer of oils and fats, it is by no means the only one, for many

other industries use oils or products of the oil industry as a major or minor component of their raw materials. The following list gives the main outlets for the various oils, but it should be remembered that it is often possible to substitute other oils when, because of shortages, or for economic reasons, it is not possible to obtain those most desired.

INDUSTRY OR USE.	PRINCIPAL OILS.
EDIBLE OILS.	
Margarine ... ... / Cooking fat ... ... / Lard compound	Groundnut, palm, cottonseed, palm kernel, copra, lard, edible tallow, hardened whale.
Salad oil	Olive, cottonseed, soya.
SOAP.	
Household and toilet soap, shaving soap, powders, flakes, liquid soaps ...	Coconut, palm kernel, tallow, palm, hardened oils, groundnut.
PAINTS.	
Oil paints, varnishes	Linseed, tung, castor, soya, fish oils.
Linoleum and allied products ...	Linseed, fish oils.
Lubricant and greases	Tallow, rape oil, special soaps.
Tin-plate manufacture	Palm oil.
Tanning	Fish oils.
Candle manufacture	Tallow, stearine (solid fatty acids from various oils).

It will be apparent that for such diverse uses as are indicated, we can expect to find various methods of treatment and preparations of the raw material before it reaches its final stage. For our immediate purpose, however, it will be sufficient if we follow the various stages through which an oil passes in the preparation of an edible oil, since this is the main outlet for the oils with which we have been concerned.

Broadly speaking, there are four main stages :

(1) Pretreatment or cleaning the crude oil.
(2) Neutralizing the free fatty acids.
(3) Bleaching.
(4) Deodorising.

The first stage is really the final stage of the crushing or extraction side, and is usually carried out in the crushing mill. Filtration is the commonest method used for removing traces of meal or other solid matter from the oil, or if this is not practicable, settlement in tanks may be adopted. Centrifugal separation is also recommended in some cases. The separated sludge or meal is generally returned to the mill and retreated with fresh raw material, the clean oil being ready for the next stage in its refining.

It is convenient at this point to refer to a preliminary separation which some oils may undergo with the object of removing some of the minor constituents of the oil known as phosphatides, the chief of which is lecithin. These substances are soluble in the oil when it is dry, but if water is added, they

can be precipitated along with some other minor gummy substances and may readily be removed from the oil by passing a mixture of oil and warm water through a continuous centrifugal separator. The crude lecithin thus produced may be further purified if necessary.

In all crude oils, a certain amount of decomposition occurs, and some of the triglycerides have broken down into glycerine and fatty acids, the amount of this decomposition is usually assessed by estimating the amount of free, i.e., uncombined fatty acids in the oil.

The amount of free fatty acid present may vary from about 0.5 per cent. to as much as 15 or 20 per cent. of the oil, depending on the type and quality of the oil, an average figure being in the neighbourhood of 5.0 per cent. F.F.A.

To make an edible oil, that is, one which is tasteless and odourless and which does not readily become rancid, it is necessary to remove the free fatty acids and other bodies which might have an objectionable taste or smell, and the most usual method is to treat the oil with an alkali, such as caustic soda when the free fatty acids are converted into soaps and subsequently separated from the bulk of the oil which may now be termed neutral, having had its acidity removed.

In addition to removing free fatty acids, caustic soda removes a considerable amount of the colouring matter from the oil together with other gummy and mucilaginous bodies; consequently, an excess of caustic soda over and above that required to neutralize the fatty acids present is necessary. The amount of caustic to be added and the manner in which it is added make this stage in the refining of an oil a critical one, since not only may undue losses occur, but faulty technique may produce an oil upon which subsequent bleaching and deodorising fail to have the desired effect.

The soap may be removed from the oil either by settling or by means of a centrifuge, the former being usually a batch process and the latter a continuous process.

In the batch process, the oil is processed in cylindrical vessels having a conical bottom, fitted with an agitator and heated by means of closed steam coils or steam jacket. At temperatures varying from 30 degs. C. to 90 degs. C., the caustic soda solution is added, the strength of alkali usually being within the range 5 to 20 per cent. according to requirements. Agitation is continued until such time that the soap or " foots " are in a condition to settle readily. After settling, the oil may be removed from the top by means of a swivel pipe, or else the foots may be removed from the bottom, leaving the oil in the vessel. The oil is usually given one or more washes of hot water to remove the remaining traces of soap.

In the centrifugal method, oil and caustic soda are continually mixed together in the requisite proportions by means of a proportioning pump, which regulates the amount of caustic, according to the rate of flow of the oil. The two liquids are intimately mixed by passing through one or more mixers wherein the free fatty acids are completely neutralized. The emulsified mixture is then passed through a tubular heater, when the temperature is raised to about 65 degs. C. and the emulsion broken up. The mixture passes into a battery of high speed centrifuges which bring about the continuous separation of neutral oil and soakstock. The neutral oil may be washed similarly to the batch processed oil, or may be separated from the wash water by further centrifuging.

Bleaching of the oil is usually carried out by means of fullers earth or similar absorbing substances which have a preferential action for removing the colouring matters from oil. In addition, traces of soap remaining after neutralizing are also taken up by the fullers earth. The process may be carried out in the same vessel as the neutralizing, or it may be done in a separate vessel. The dried oil is agitated with between one to four per cent. of earth at a temperature usually between 80-120 degs. C. The mixture is then passed into a filter press which retains the earth on the cloths, allowing the clear, bleached oil to pass through.

Although clean and bright and pale in colour, the oil still has a pronounced smell and taste, so the next stage is the removal of all those substances which give the oil its characteristic odour and taste by a process of deodorisation which, stated simply, is steam distillation under a vacuum. Live steam is passed into the oil, heated to a high temperature in a closed vessel whose outlet leads to a condenser where the issuing vapours are trapped. A temperature ranging from 160-230 degs. C. or more may be used in order to get a satisfactory result in a reasonably short time, together with a vacuum which is usually between 4.0 mm.-8.0 mm. absolute pressure. While at this elevated temperature, the oil is very susceptible to oxidation and, therefore, great care has to be taken to ensure that there are no air leaks into the plant which might in any way damage the oil.

After a period varying from two to eight or more hours, the oil is cooled down to room temperature before allowing the vacuum to be broken. The cooling may take place in the same vessel, or else the hot oil may be transferred to a separate cooler.

The cool oil is now ready for use either in margarine blending or for direct chilling and packing as a shortening or cooking fat; whichever way it is used, it is important to handle the oil as little as possible and to reduce the time interval between the completion of deodorising and the packed finished product as much as possible, in order to maintain a high quality standard.

PART II

COMPOUND and PROVENDER MILLING

by

A. S. MOORE, A.M.I.Mech.E.

COMPOUND AND PROVENDER MILLING

(By A. S. MOORE, A.M.I.Mech.E.)

In the first year text book, a survey was made of most of the machinery met with in compound and provender mills. The treatment afforded to individual machines was necessarily brief, the object being to paint broad outlines of the whole industry. The Second Year allows us to retrace our steps to the starting point and amplify our examination of the machinery already referred to, although this does not preclude the introduction of some machines which have not hithertofore been mentioned.

CHAPTER I.

PNEUMATIC AND MECHANICAL SHIP ELEVATORS

BUCKET ELEVATORS—SHIP TYPE.

The chief merit of this type of intake elevator is its comparatively low initial cost, its low power consumption per ton of material handled and its ability to handle a variety of materials having a wide range of characteristics, from damp or sticky meals to comparatively large, irregular shaped lumps. The conveying principle of the elevator is identical with that of the mill bucket elevator, although the special duty of the ship elevator requires some differences in design. As with the ordinary mill elevator, the buckets may be carried upon belting, or one or two chains.

Generally speaking, chains are used where oily or wet material is being handled. A single chain is used in elevators of small capacity and short centres, and two chains for large elevators. The chains used are of the familiar Ewart type which will be described in Chapter III.

For use with dry materials, cereals for instance, ship elevators are fitted with belts which may run at a speed in the neighbourhood of 400 to 500 ft./min. There is a considerable difference in the size of the head and boot pulleys in ship elevators, the boot pulley being kept as small as possible to reduce the dredging of the buckets through the material, whilst a good delivery at the head requires as large a head pulley as possible. With chain elevators, the delivery at the head may be improved by what is known as the dumper principle in which, instead of allowing the return side of the chain to follow a direct line between the head and boot wheels, it is carried under the head pulley for a short distance which allows the full effect of gravity to assist the discharge of the buckets (Figs. 41 and 42). This method of delivery is also referred to as gravity discharge, and is chiefly used with slow chain speeds and sticky materials. The bearings of the shaft carrying the boot pulley are mounted in

guides and located vertically by a screwed rod complete with locking nuts. Sometimes, one of the lock nuts on each side of the boot is replaced by a handwheel (First Year text-book, page 118). It should be noted that the open boot of the elevator has bars stretching between the side plates which protect both the buckets and any object with which the elevator may come into contact.

The elevator casing is made of heavy gauge sheet steel and is fitted with inspection doors along its length. The belt carrying the buckets may be of cotton canvas, rubber and canvas, or balata; balata belting is composed of a cotton base impregnated with gutta percha. The buckets may be pressed from one piece or may be built up from the flat and rivetted along the seams. Typical buckets will be described under mill elevators as will also the method of fastening buckets to belts or chains.

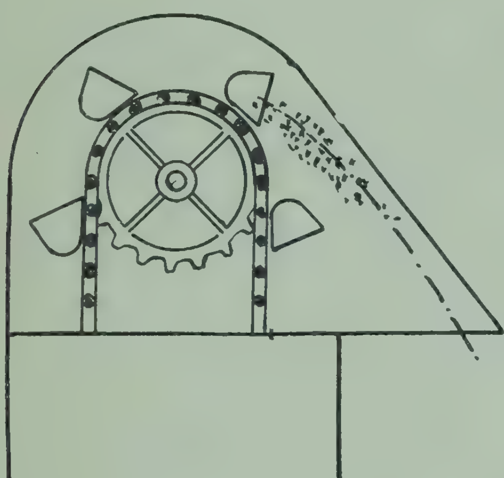


Fig. 41

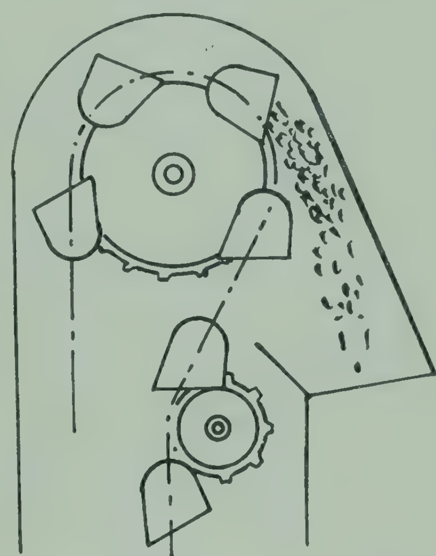


Fig. 42

The drives to the elevator and to the beam lifting gear are usually obtained from one electric motor through a system of countershafts and change speed drives. The elevator head shaft may receive its power through a chain drive running the length of the counterpoise beam to a countershaft mounted on the top of the quay tower, or the motor may actually be mounted on the elevator itself. Power consumption averages about one-half horse power per ton of material lifted per hour. The average performance of a bucket elevator of this type is about 50 per cent. of its maximum capacity but will vary with the type of cargo handled. The loss of capacity is occasioned by the reduction in the feed to the elevator after it has removed the bulk of the material in the vicinity of the boots when trimming has to be resorted to. Trimming, or feeding of the elevator may be done manually with small parcels, or mechanical ploughs

may be used with larger parcels. The ploughs are heavy boards hauled mechanically through the pile, under the guidance of an operator. With large homogeneous loads, the elevator will be moved from one part of the load to another to reduce trimming to a minimum. Each journey of the elevator through the depth of the load is referred to as a " sink."

PNEUMATIC ELEVATORS—SUCTION TYPE.

The movement at high velocities of large volumes of air by the creation of a pressure unbalance at two ends of an enclosed path is used as the conveying medium in this type of

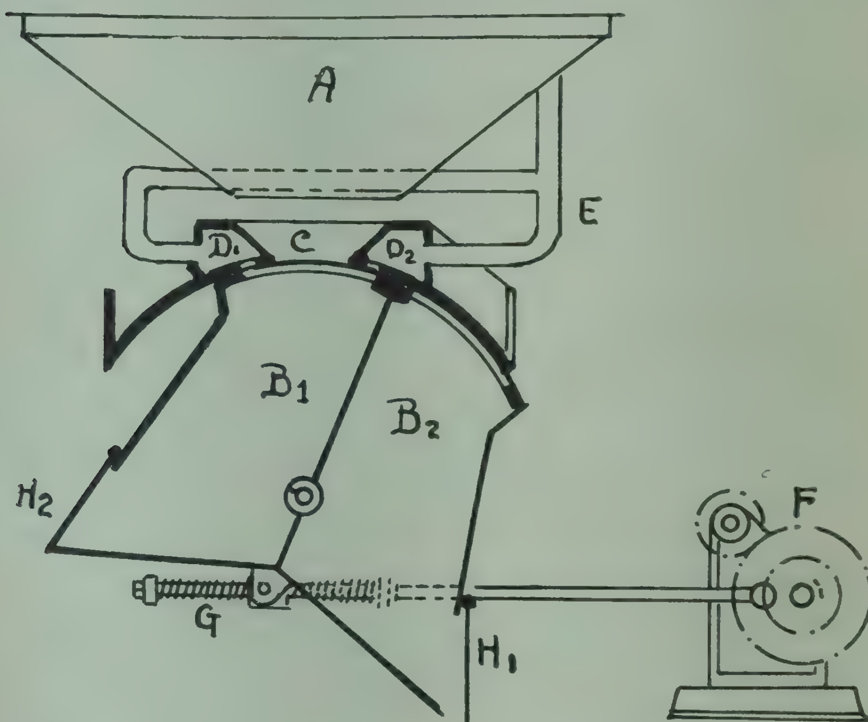


Fig. 43

elevator. The pressure unbalance is obtained by the use of either a reciprocating vacuum pump or a rotary exhauster, and the plant required to make use of the resulting air movement is composed of the following items :

(1) A receiver in which the air and the conveyed materials may be separated.
(2) Air piping to connect the air stream with the material and the exhauster, via the receiver.
(3) A nozzle for controlling the flow of air and material to be conveyed.
(4) A discharger for delivering the separated material from the receiver without breaking the contained vacuum.
(5) A dust separator to clean the air leaving the deposited material before it reaches the pump or exhauster.

Fig. 51 of the First Year text book shows the relationship between the above items, except that the dust separator is not shown. It is not too much to say that the success of suction plants depends upon the effective mixing of material and air at the suction nozzle, and the practice of admitting secondary air into the system, first used by the late Mr. F. B. Duckham of the Millwall Dock Co., London, made possible the successful modern intake plant. The secondary air stream is introduced into the system at the suction nozzle by the use of a manually

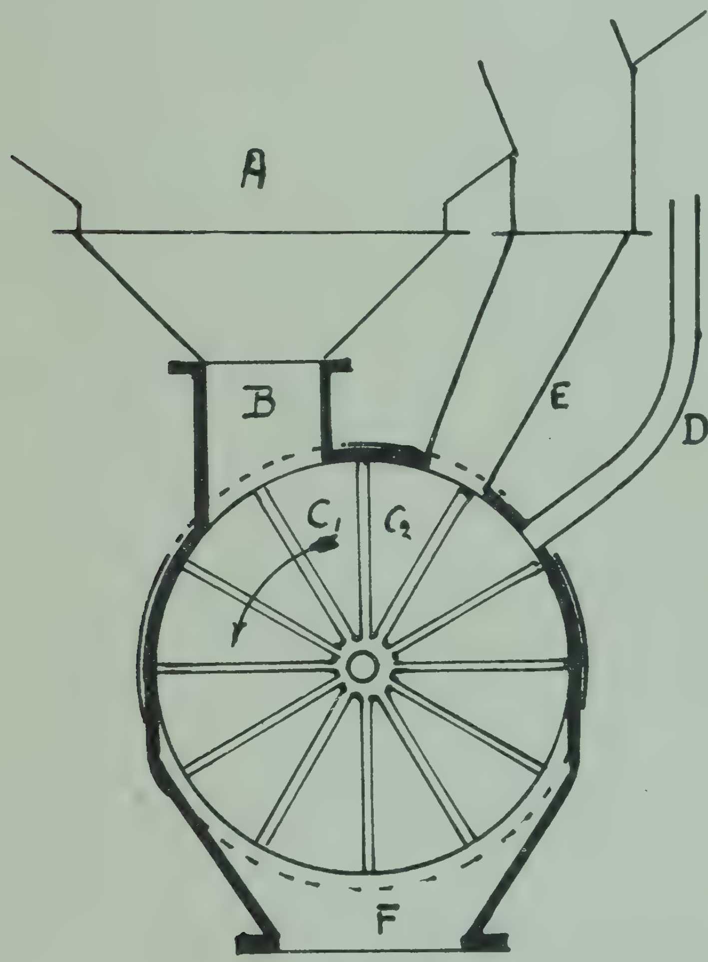


Fig. 44

controlled valve or an adjustable sleeve which forms part of the nozzle construction.

Early suction plants consumed as much as three horse power per ton of material handled, and there is no doubt that a considerable part of this power was frittered away in overcoming losses of vacuum due to air leakage. A critical point in the maintaining of vacuum occurs in the transferring of the material from the receiver which is under vacuum, to the conveying system which is at atmospheric pressure. This difficulty is sur-

mounted by the use of an air sealed discharger, two types of which are illustrated in Figs. 43 and 44.

The discharging tipper seal shown in Fig. 43 is mounted on the bottom outlet of the receiver (A). The tumbling box, having two chambers (B1) and (B2), oscillates about a pivot supported from the receiver. The rocking motion is imparted to the box by a connecting rod and crank mechanism driven at (F). Each of the chambers (B1) and (B2) have open tops and are fitted with freely hinged doors (H1) and (H2). The top of the moving box is shaped in an arc of a circle about the pivot as centre, and mates with the fixed part of the device, also shaped to a concentric arc just sufficiently larger to permit movement between the two. The fixed arc is perforated at two points to give access to pockets (D1) and (D2) which are interconnected by the pipe system (E) which also links them to the inside of the receiver. The centre of the fixed member is cut away to form the port (C).

The operation of the discharger is as follows: The material to be discharged falls from the receiver (A) through the port (C) into the chamber (B1). The chamber (B1), by virtue of its connexion with the receiver through the aperture into pocket (D1), is under a vacuum, and the door (H2) is held tight against ingress of air by the preponderance of pressure on the outside. The rocking action commences under the action of the driving mechanism (F), and the inlet to chamber (B2) moves towards the position shown occupied by the inlet to chamber (B1) in the illustration, but on the opposite hand. At the limit of its travel, the chamber (B1) will be in a position comparable to that shown occupied by (B2), but on the other hand, in which position the interior of the chamber will be at atmospheric pressure due to the ingress of air through that part of the top opening which will have cleared the fixed member. (Compare with (B2) in the figure).

The pressure balance being restored on door (H2) it will open under its own weight aided by the weight of the material to be discharged. In moving the full chamber (B1) over to the discharging position, the empty chamber (B2) will have moved into the filling position, and in doing so will have been exhausted through the aperture into pocket (D2) which is connected by pipe (E) with the interior of the receiver. All rubbing faces of the mechanism in communication with different pressures are fitted with seals, usually of leather or rubber. The repetition of the rocking action is continued until all the material has been discharged with a minimum of vacuum loss. In the event of a foreign object such as a stick of wood jamming in the tumbling box, the spring (G) fitted on the connecting rod protects the mechanism from damage.

The rotary seal shown in Fig. 44 is a much simpler device than the tipper seal. The rotary seal consists of a rotor having pockets (C1), (C2), etc., rotating inside a box so constructed that in the top half of its path the rotor has only just running clearance from the stator. As the rotor revolves in the direction shown by the arrow, each pocket is first presented to the pipe (D) which, being connected to the inside of the receiver (A), exhausts the pocket. In the arrangement shown, the dust separated from the air stream by a cyclone separator inside the receiver is next discharged into the pocket through chute (E), after which, as the pocket moves underneath the inlet throat (B), it receives its quota of material to be discharged. The material is discharged through the outlet (F) during the lower half of the pockets' travel.

A modern refinement to pneumatic intake plants is the inclusion of the quay conveyor in the pneumatic circuit, in which the intake pipes discharge the conveyed material straight on to the conveyor bands which run in an air-tight casing. The conveyor bands are travelling at air speed, thus eliminating shock, and deliver their load through tipper seals into the silo building. This arrangement is patented by Messrs. Henry Simon, Ltd., who claim that the intake unit is completely dustless and point out that, in their arrangement, a considerable amount of heavy machinery can be removed from the quay and accommodated inshore.

Pneumatic plants are particularly well suited to grain intake and in handling wheat the power consumption varies from less than 1 h.p. to $1\frac{1}{2}$ h.p. per ton per hour. Air speeds employed are in the neighbourhood of 8,500 ft./min. at the nozzle, being reduced to 3,000 ft./min. before delivery. Air volume is about 50 cubic feet of air per minute, per ton per hour, of grain lifted. The average performance of a pneumatic plant may be as good as 80 per cent. of the rated maximum capacity due to its considerable self trimming properties.

CHAPTER II.

HANDLING PLANT FOR BAGGED MATERIALS

It is difficult to imagine industry being carried on without the aid of the machines which are used for the movement of materials. Some industries, it is true, use fewer handling machines than others. But even in those industries where a great deal of manual lifting is done, manually operated machines are frequently used to obtain the "mechanical advantage" from simple gearing or with the simple rope and single pulley hoist to achieve a more convenient application of effort. It should be noted that the term "mechanical advantage" used

in this connexion has more than its usual literary meaning, and is specifically employed to denote the relationship that exists between the effort applied to a machine and the load overcome.

A typical example of convenience resulting from the use of a mechanism is provided by the building operatives' practice of hoisting buckets of mortar on the end of rope which is passed round a pulley. Here, there is no gearing to provide a "mechanical advantage," but the convenience of applying effort to the rope in a downward direction instead of a straight pull up will be readily appreciated.

Centuries ago, all the elevating of materials would be performed by men carrying the materials up stairs or ramps. This would, no doubt, be followed by the wheeling of primitive carts and barrows up the ramps, thus allowing each single load to be greater than that which one man could carry. Where labour was plentiful, there might be found the co-ordination of effort represented by the human chain with the conveyed material passed from one man to another along a continuous line of labourers joining the two ends of the conveying distance. The builders of ancient store houses were no doubt persuaded, by this limited means of elevating materials, to keep their store houses long and low. The demand on ground space being no deterrent when land was plentiful and cheap.

It is difficult to say whether the invention of lifting machines encouraged the erection of tall buildings or whether the growing scarcity of land on suitable sites made tall buildings necessary with this necessity mothering the invention of elevating machinery. Be that as it may, the development of geared hoists from the simple builders' hoist seems to be logical and enabled single workmen to elevate loads considerably greater than any one man could have lifted unaided. This simple case introduces to us the idea or principle of mechanical advantage, and as the practical application of the principle is met with so widely in the machines we have to consider its mention here may not be out of place.

In machines in which the movement of the load point bears a constant relationship to the movement of the force point, this relationship is called the "velocity ratio," and the ratio of effort to work is called the "mechanical advantage."

Fig. 45 shows a diagram of a simple two-step pulley hoist in which the load attached to the smaller diameter is represented by W and the effort applied to the larger pulley is represented by P. If the diameter of the small pulley is 1 ft., then every revolution of the pulley will move the load π ft. If the diameter of the large pulley is 3 ft., then every revolution of the large pulley will involve a movement of the effort through a distance of 3π ft. The relationship between the movement

of the load and the movement of the effort will remain constant for any number of revolutions of the pulley and this is the velocity ratio, referred to above, that is :

$$\text{Velocity Ratio} = \frac{\text{Movement of Effort}}{\text{Movement of Load}}$$

In the same figure the load W will exert a moment about the pulley spindle equal to $\frac{W}{2}$ lb. ft., whilst the moment of the effort will equal $\frac{3P}{2}$ lb. ft., so that in the absence of friction a balance of load and effort will be obtained when $\frac{3P}{2} = \frac{W}{2}$ from which it may be calculated that $P = \frac{W}{3}$ or $W = 3P$ or $\frac{W}{P} = 3$.

This ratio of $\frac{W}{P}$ is the mechanical advantage of the machine which, in this case, is 3 to 1.

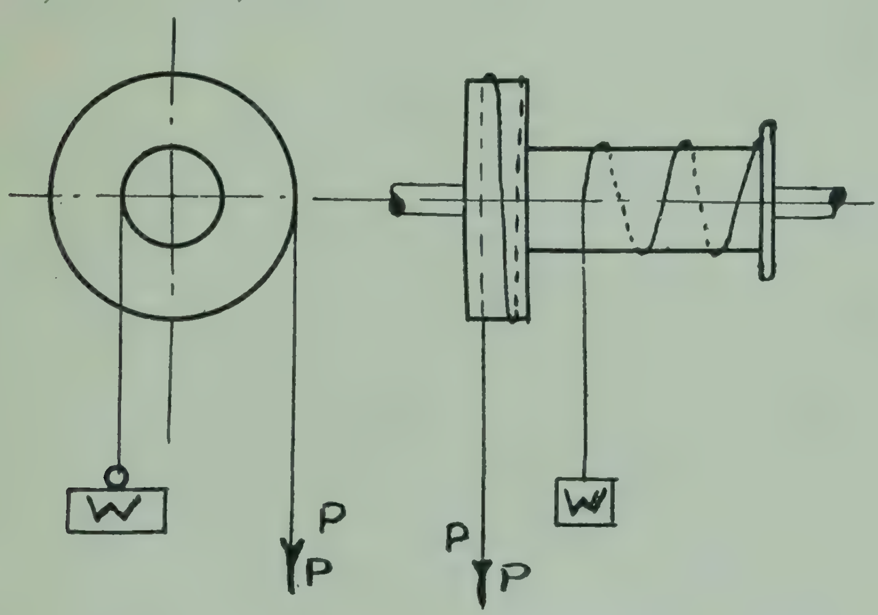


Fig. 45 **Simple Two Step Pulley**

The movement of a force through a distance involves the doing of work which is measured by the product of the force and the distance through which it moves. If there is no move-

ment, no matter how large the force that is being applied, there is, technically, no work being done. The unit of work is the foot lb. and is the amount of work done by a force of 1 lb. in moving through a distance of 1 ft.; or a force of ½ lb. moving through a distance of 2 ft., and so on.

In the example Fig. 45, the work done by the force P in moving the pulley round once is equal to 3π P ft. lb. and the work done on the load is equal to π W ft. lb. In an ideal machine having no friction losses, $3\pi P = \pi W$. In any practical machine some effort is lost in overcoming friction, so that 3π P will always be greater than π W, and the ratio between the two is called the efficiency of the machine and is usually expressed as a percentage, i.e.

$$\text{efficiency} = \frac{\text{Work got out}}{\text{Work put in}} \times \frac{100}{1} \text{ per cent.}$$

Due to the necessity of friction, 100 per cent. efficiency is unattainable, and although therefore gearing may be used to obtain a mechanical advantage, there is always some loss of effort in overcoming friction. The gearing of machines is not always resorted to to obtain mechanical advantage, but is often used to change the speed of the effort to some other speed more suitable to the work required. The invention of mechanical prime movers and particularly of electric motors which have a limited speed range made the use of gearing for speed change purposes essential. The use of engines to drive machinery resulted in the sphere of mechanical handling in the development of the power driven winch. Winches have been and are still used to handle all kinds of materials under widely differing conditions. As might be expected, differences in the design of winches began to appear as the work required from them became split up to specialist categories and one of these design developments led to the familiar friction hoist. Friction hoists, the design and operation of which were described in the first year text book, are made in various sizes but a limiting size for bag handling work is usually about 7 cwt. Rope speeds up to 700 ft. per minute are not uncommon, and in a hoist of this size a 15 h.p. motor would be fitted. Friction hoists, like many other machines, are open to mishandling, and carelessness in slinging loads can be a real menace.

Wearing plates should be fitted to all hoist door lintels to reduce attrition upon the lifting rope. Hand grips at each side of the door opening are required by law, as are toe boards, and it is common practice to find safety belts worn by the hoist operator fastened by a length of cable to the ceiling above the operator. Routine inspection of hoist equipment is very necessary for, apart from normal wear and tear, rats have been known

to eat through lifting and control ropes and to gnaw at the rawhide friction pinions and gears.

Whilst the versatility of the friction hoist and its slight demand upon mill space will always make it a valuable item of intake plant, the restriction upon intake capacity resulting from its intermittent action made the continuously operating elevator a necessary development. To-day, there are a variety of continuous intake bag elevators, both inclined and vertical, in constant use. Three of these types suited to the handling of bagged materials are the inclined push bar elevator, the vertical push bar elevator and the swing tray elevator. As well as these elevators, there are a couple of inclined conveyors which do duty as intake elevators and they will be considered later.

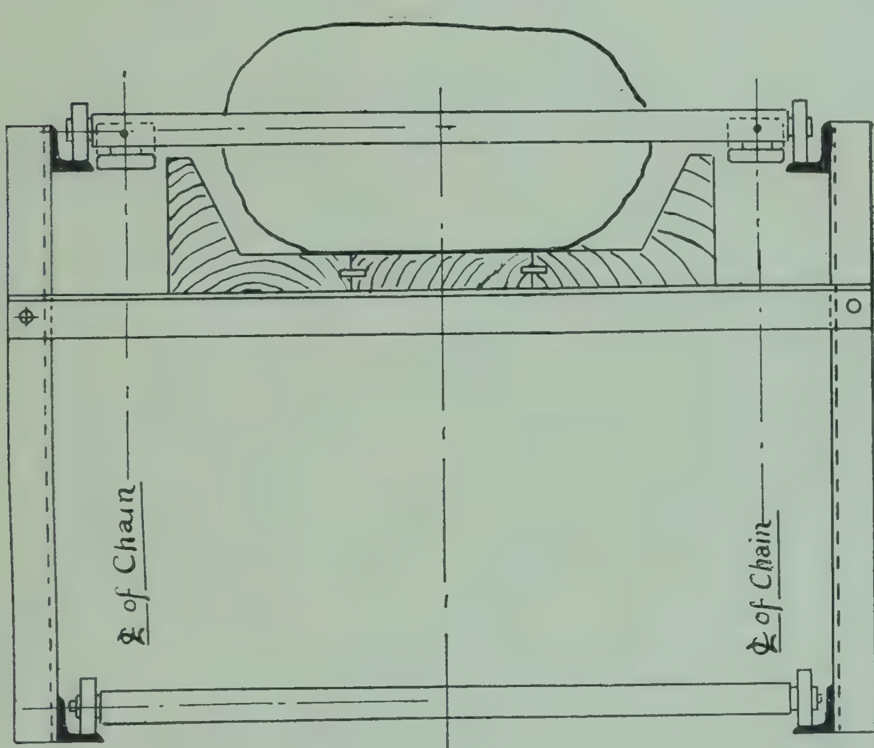


Fig. 46 **Cross Section of Inclined Sack Elevator**

INCLINED SACK ELEVATOR.

Most of the early types of inclined sack elevators are of the open design in which the bags are pushed by bars up a fixed ramp which is completely open to view. The ramp itself is usually of timber with a good hardwood face. The carrier bars of steel may be of circular or rectangular cross section or, in other cases, may be of rolled steel "Tee" section or may be built up to "Tee" section from angle iron. The bars, chains, rollers, and the tracks upon which the rollers run are all open

to view, with suitable fencing erected some distance from the elevator to keep people from danger. The open construction of this type of elevator lends itself to ready observation of its design, construction and operation (Fig. 46). The head sprocket driving mechanism is, however, often inaccessibly located, and an interesting feature of this mechanism is the device which is incorporated to prevent the elevator running back under load should the driving motor be stopped.

This device, of course, may be a simple pawl and ratchet, but frequently a friction cam mechanism is used for preventing run back.

A typical friction wheel and eccentric cam are shown in Fig. 47. The friction wheel (A) is mounted on the first motion

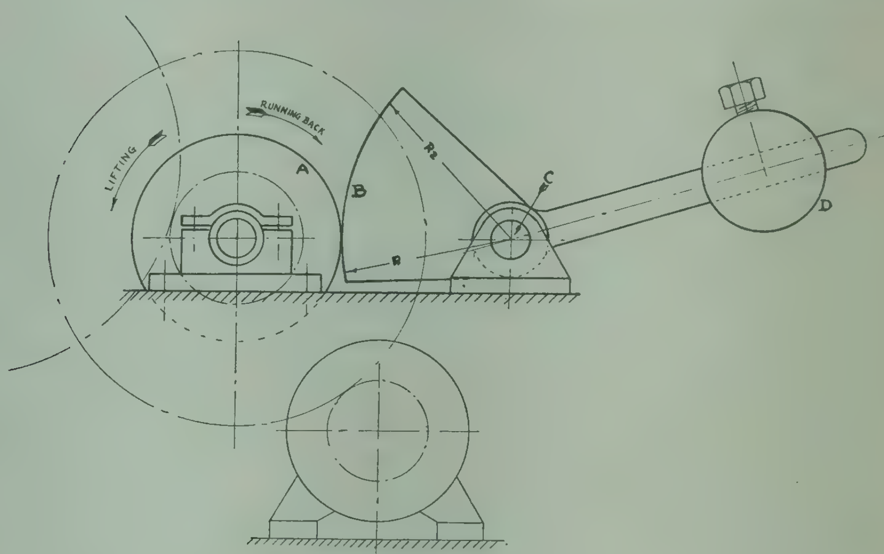


Fig. 47

shaft and in contact with it is the counterbalanced cam (B), the arc of whose outer edge is eccentric about the spindle (C), that is the distance R is less than the distance R_2. When the elevator is lifting, the friction wheel (A) is rotating in an anti-clockwise direction, thus tending to lift the cam (B) and run out of contact with it. The counterweight (D) is adjusted to maintain light running contact between the cam and the friction pinion. Should the elevator for any reason attempt to run back, the friction wheel (A) will reverse its direction, that is, in the arrangement shown in the sketch, it would run in a clockwise direction and move the cam (B) downwards. The downward movement of the cam (B) would continue until the increasing distance of the cam face from the spindle (C) would jam the friction wheel and thus prevent any further movement.

This action takes longer to describe than it does to occur,

and a fraction of a revolution of the elevator headshaft in the running back direction applies this very effective brake.

Where a pawl and ratchet are used to prevent the elevator running back, the excessive wear resulting from having the pawl constantly bouncing on the ratchet teeth may be avoided by fitting a friction operated pawl locating attachment similar to that shown in Fig. 48, which, apart from reducing wear, eliminates noisy operation, and should the elevator run back, ensures positive engagement of the pawl. The ratchet wheel (A) is mounted on the elevator headshaft and a friction drum (C) is part of the ratchet casting.

Round the friction drum are fitted the steel straps (D) which are lined with a friction material like "Ferodo." The straps are bolted together on the pawl side of the drum and carry a pin (E) which is located in a slot in the pawl (G) hinged on pivot (H). The other ends of the friction straps do not meet but are pulled towards each other by the spring loaded bolt (F), the adjustment of which determines the grip of

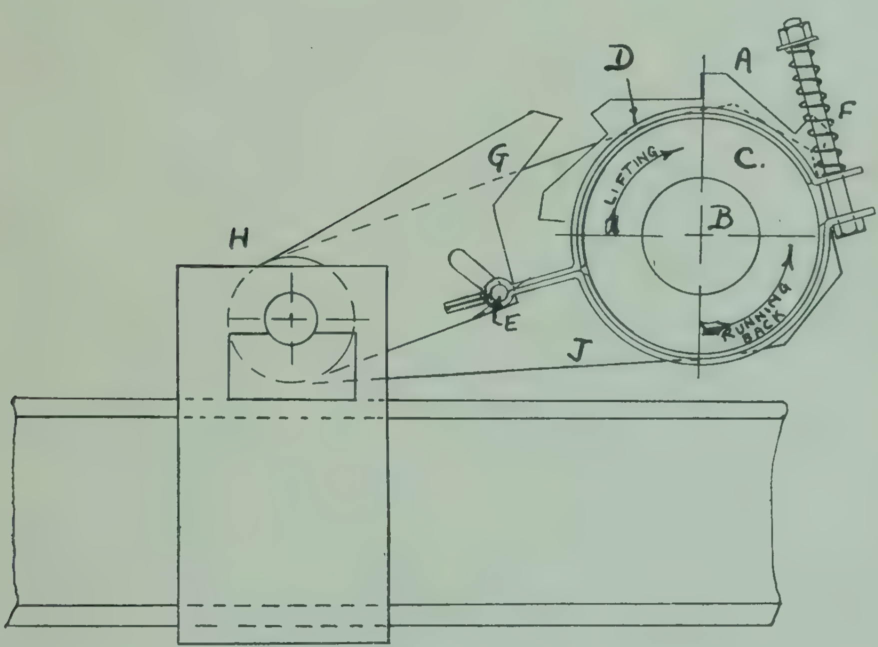


Fig. 48

the straps upon the ratchet casting. When the elevator is lifting, the ratchet wheel is rotating with the headshaft in a clockwise direction and tending to turn the friction straps with it, thereby lifting the pawl clear of the ratchet teeth. Should the elevator run back, the direction of the ratchet will be reversed and the friction strap following it will push the pawl into the ratchet teeth, thus stopping any further movement.

The lifting speed of the elevator is likely to be about 90 feet per minute. Most inclined elevators deliver over the top sprockets, but they are sometimes made with the ramp fitted with hinged or sliding sections at various heights. As each of these movable sections or doors are part of the ramp, when one is opened any bags which are pushed up the ramp upon reaching the opening will fall through to be discharged through the return chains on to the floor at that level (Fig. 49).

The open type inclined sack elevator occupies a fair amount of floor space unless the angle of elevation

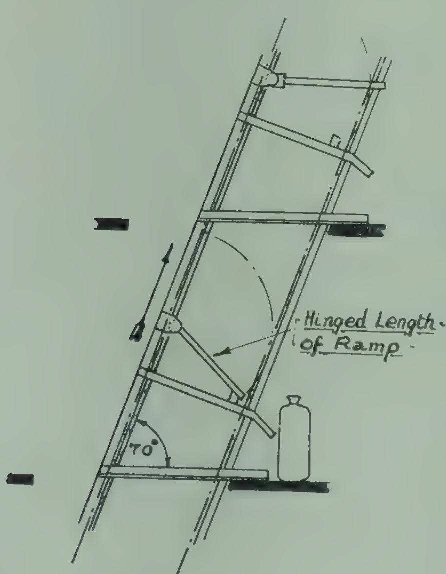


Fig. 49

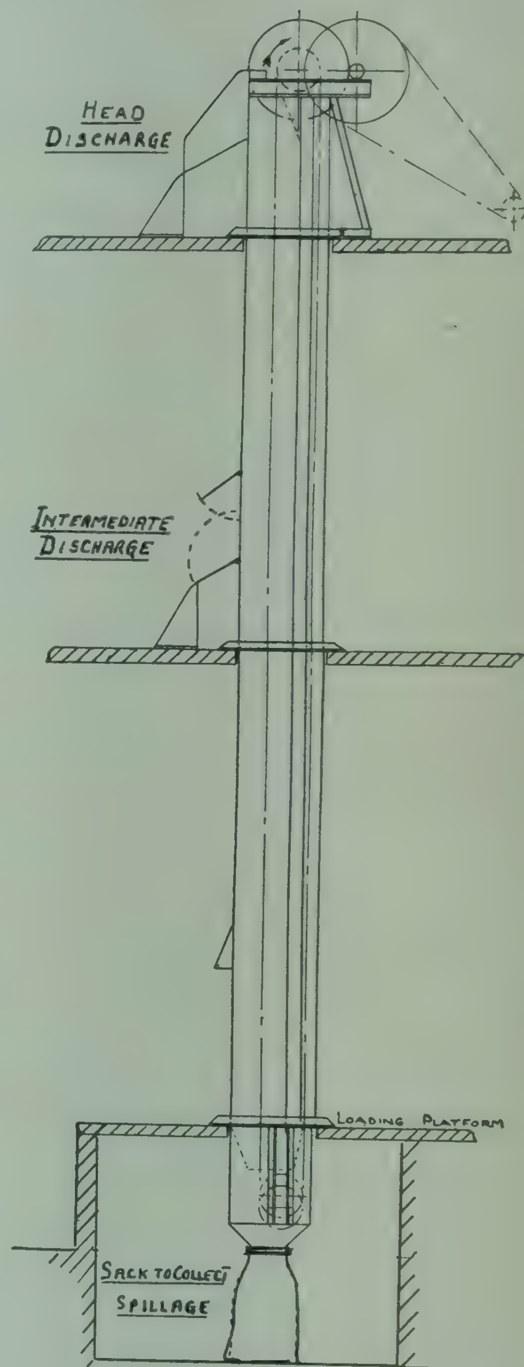


Fig. 51 Vertical Sack Elevator

is large, and of later years sack elevators of the enclosed vertical pattern have been put into use with a consequential saving in floor space.

THE VERTICAL SACK ELEVATOR.

The Spencer patent elevator is of all steel construction except, of course, such parts as bearings and possibly chain sprockets.

The chain itself is of all steel construction and is totally enclosed over practically all of its path. The cross sectional plan (Fig. 50) gives a good idea of the shielded chain and carrier paths. Apart from the safety factor, the sinking of the chains into the recesses shown minimizes the possibility of a delapidated bag fouling the chains. This elevator can be constructed to receive and discharge at any floor, although the particular elevator whose main lines are shown in Fig. 51 can only be fed at the bottom level and discharges on to the top floor or any intermediate floor. Discharge tables may be arranged to deliver the bag at floor level or at shoulder height.

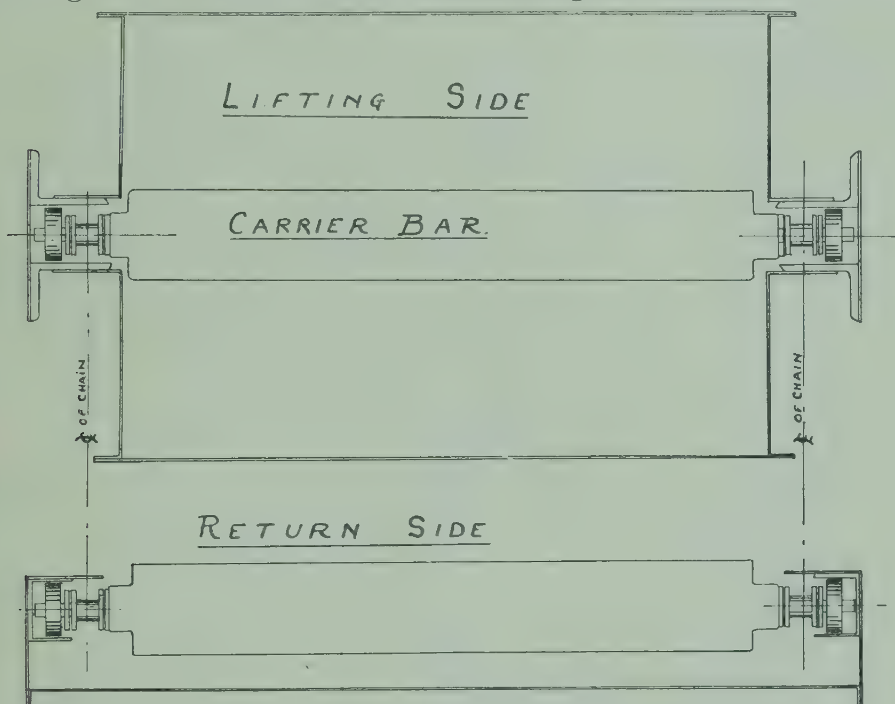


Fig. 50 **Plan cross section of vertical sack elevator**

The hinged discharge trays form part of the elevator casing when not being used and are opened up when required. The movement of the discharge tray is communicated through a suitable linkage to a hinged portion of the back plate of the uptake leg. As the delivery tray is opened, the hinged part of the backplate swings forward to act as a throw-off for the ascending bags. See Fig. 52 in which the open position of the mechanism is shown dotted.

In this type of delivery tray it is important to make sure that, in the open position, the centre line of the link connecting the tray with the back throw-off plate lies below the axis about which the drop tray is hinged, otherwise a firmly seated bag coming up against the throw-off plate may push the throw-off plate back into place and, in so doing, bring the drop tray very violently into the closed position. Apart from the fact that the

bag will have passed the delivery point, severe injury is likely to be sustained by any workman who happened to be in the path of the drop tray.

Vertical sack elevators of this type are often damaged by being fed with bags other than those for which they were designed. Bagged slab cake, for instance, is most unsuitable

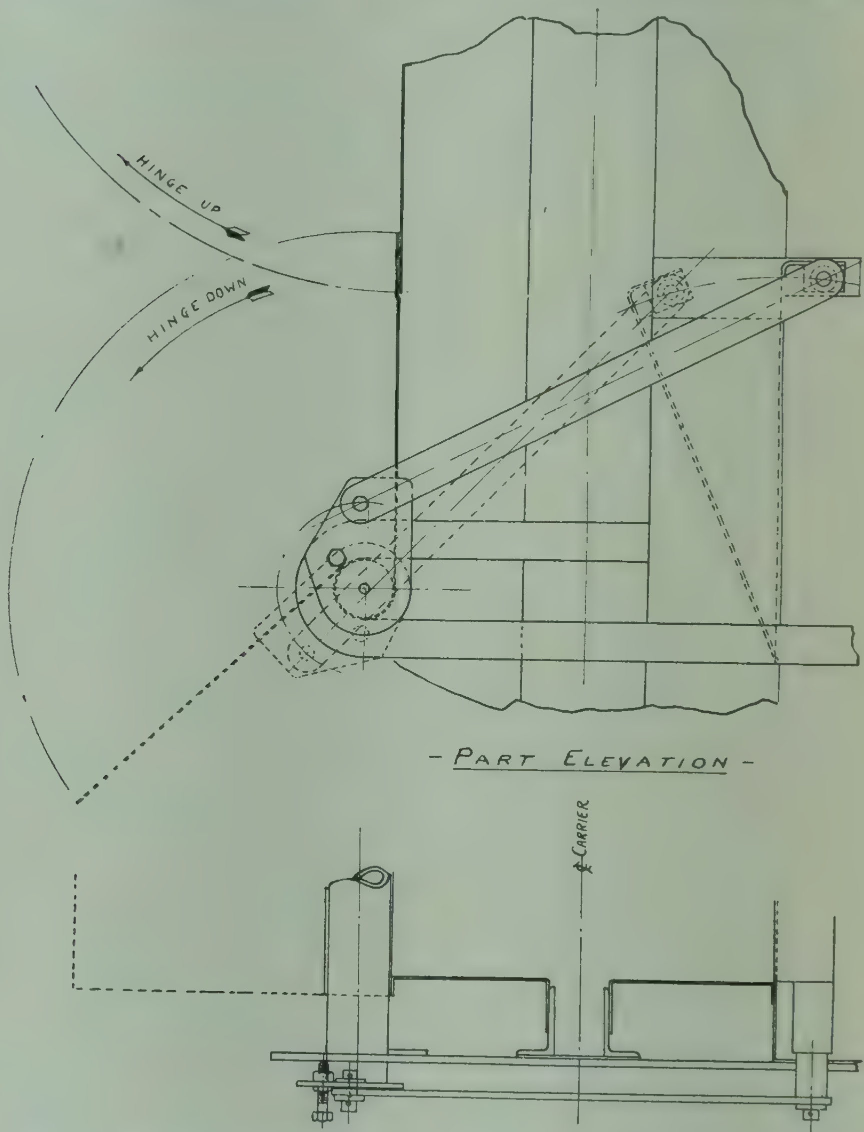


Fig. 52 Vertical Sack Elevator, Hinged Discharge Tray and Throw off

as a load for this elevator. Unsuitable loads may result in torn casing, broken chains and buckled throw-offs.

The boot of the elevator may be located inside a small sacking-off bin into which spillage from broken bags drops. This spill bin saves a great deal of cleaning time when spillage occurs (see Fig. 51).

SWING TRAY ELEVATOR.

Whilst it is doubtful if a swing tray elevator could compete

with a modern vertical sack elevator of the push bar type, a well designed swing tray elevator is a more versatile machine, being very much more accommodating in the variety of size and shape of parcel it will handle satisfactorily. The large amount of floor space occupied, however, is a serious objection.

Swing tray elevators may be loaded either by the workmen placing the bag directly on to the travelling tray, or by placing the bag on a loading platform to be picked up automatically by the tray and similarly, for discharging, the bag may be removed directly from the moving tray by hand or it may be automatically deposited by the tray on to a discharge platform. To suit

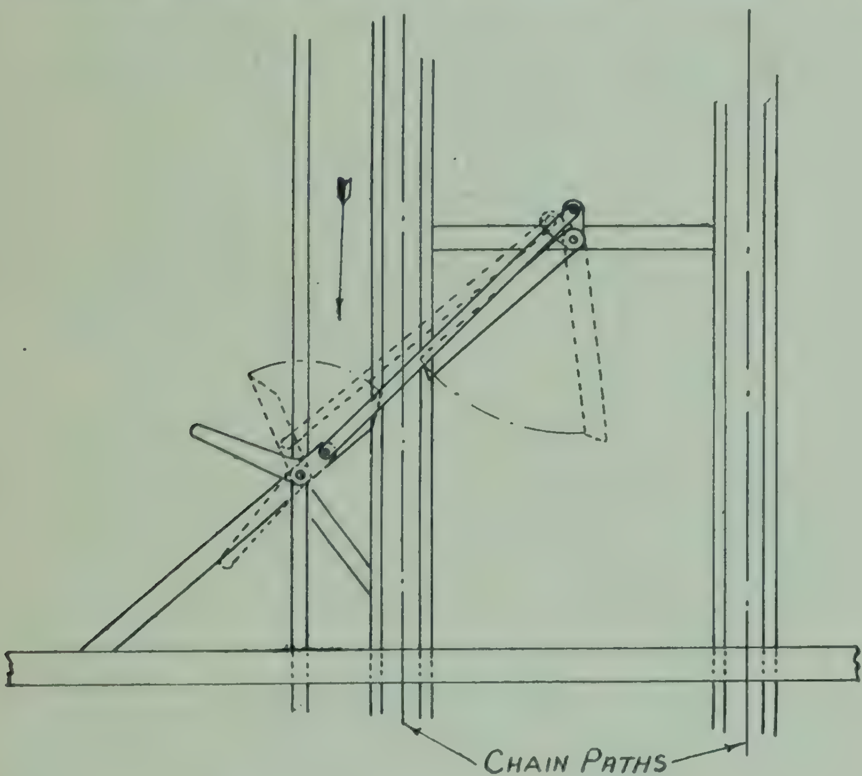


Fig. 53 Swing Tray Elevator Automatic Take off

each of these two conditions, some difference in tray design is necessary. In the first case of direct manual loading and unloading, the moving tray may be constructed from a solid steel plate or timbers supported upon a strengthening framework or cradle. In the second case where the bag is deposited upon an open grill in the path of the tray, the tray must be made of a trunk and branch or skeleton pattern so that it may pass the fixed grill without fouling. Except with an elevator which is always loaded and discharged at the same points, the loading and discharge grills must be capable of being moved into and out of the path of the trays at will, and a hinged arrangement of grill is shown in Fig. 53, in which the take off fingers are shown dotted. An alternative to the hinged arrangement is to

have both the loading and discharge grills mounted on rails forming part of the elevator structure and arranged in such a way that they may be lowered or raised to any desired level.

Automatic loading and discharging should always be used where parcels of more than $\frac{3}{4}$ cwt. are being handled and, in fact, this method of loading is used as a convenience even with comparatively light parcels. The non-automatically loaded elevator may be loaded and discharged on the up side or on the down side, or loaded on one side and discharged on the other side, whichever may be most convenient, whereas the automatically loaded elevator is loaded on the up side and discharged on the down side.

An important feature of the swing tray elevator is its ability to convey the carried load round the terminal pulleys

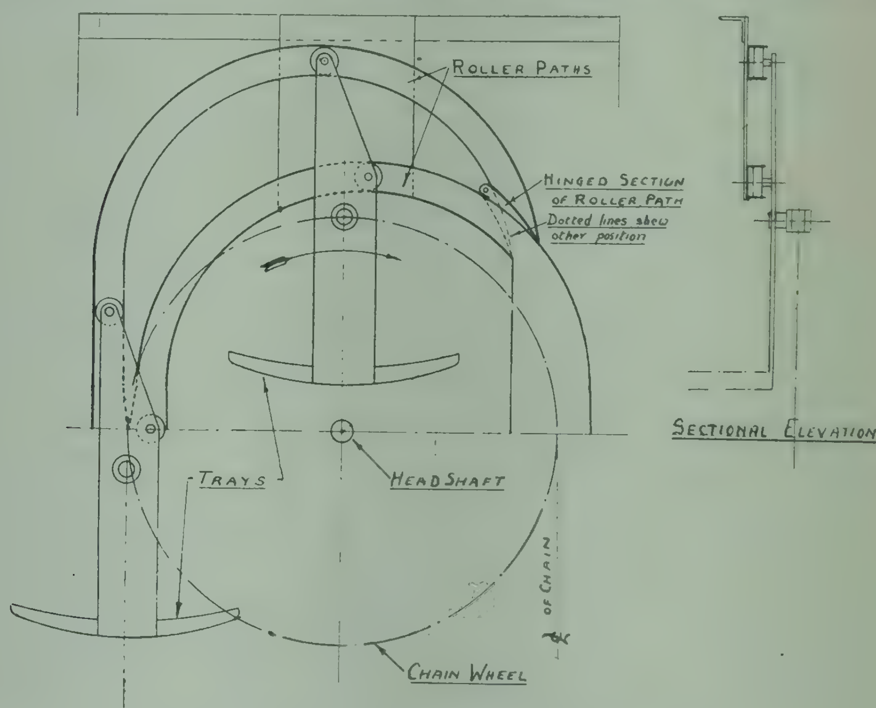


Fig. 54 Swing Tray Elevator, Anti-Tipping Device

without spillage and a patented anti-tipping gear is shown in Fig. 54. In this device, each of the arms supporting the tray from the chain is extended and fitted with two rollers so located that as the tray approaches the head pulley of the elevator, the rollers of each arm engage in tracks fastened to the elevator superstructure in such a way as to provide a rigid three point suspension for the tray when it is undergoing a change in its direction of movement. In this way, it is made impossible for the tray to tilt, which might otherwise easily occur if it should happen to be badly loaded.

Lateral movement of the trays is limited by the guides which extend the full height of the elevator. An average chain speed

is about 40 ft. per minute and power consumption is very low compared with, say, a cage hoist. In common with all belt or chain elevators, the swing tray elevator should be driven by connecting the drive to the headshaft so that should the chain tension be allowed to slacken the weight of the chain plus any load will help to keep the chain in contact with the head sprocket teeth.

If the boot sprocket should be driven, it will become necessary to keep the chain tension much higher to avoid the possibility of the chain jumping the boot sprocket teeth. The constantly maintained tension necessary to successful boot sprocket driving will obviously increase the rate of wear on chains, sprockets and shaft bearings.

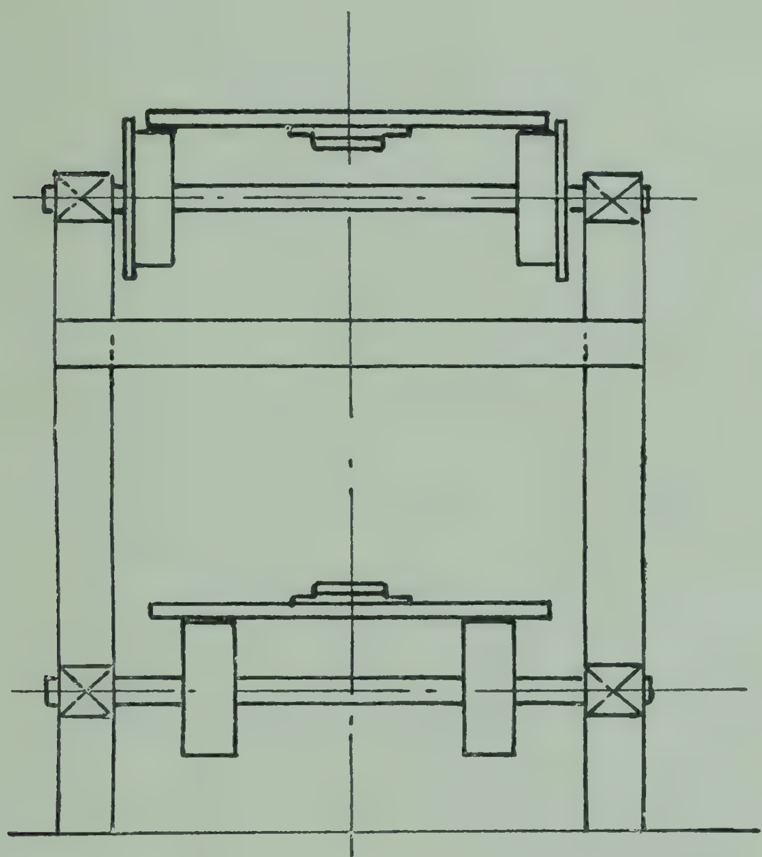


Fig. 55 Slat Conveyor, Single Chain

INCLINED CONVEYORS.

These conveyors are widely used as elevators for the intake of materials on to lower floors, but as they occupy an excessive amount of floor space, their use for lifting loads to upper floors is strictly limited except where they are erected outside the factory and are used to traverse a yard or quay or other space separating the transport vehicle from the warehouse, in which case, their function becomes as important as a conveyor as it

is as an elevator. Inclined intake conveyors invariably use a continous band, semi-continuous slats or bars, for the carrying of the bags.

The design of a slat conveyor is readily apparent from diagrams 55 and 56. Fig. 55 shows the slats connected to a single centrally located chain and supported on flanged idler rollers carried on spindles supported on the framework of the conveyor. Fig. 56 shows the slats fastened near each end to chains having attachment links to which are fitted carrier rollers running in channel iron tracks. A conveyor having carrier bars instead of wide slats is of the slat conveyor family and is differentiated from the bar type elevator in that the bags are carried on the bars of the conveyor and not pushed by the bars as in the bar elevator. Belt conveyors for bags, if lifting at all steeply, may

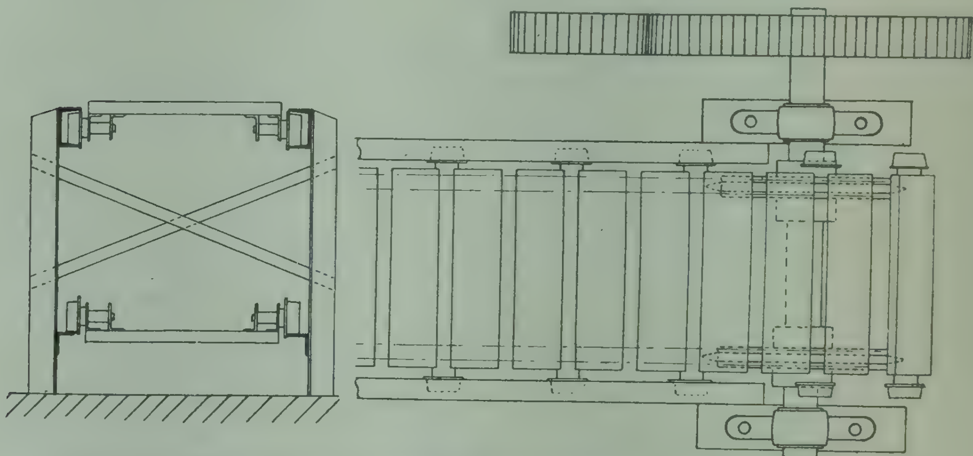


Fig. 56 Slat Conveyor, Double Chain showing : left, Cross Section, and right, Plan

have slats fastened to the belt at intervals to provide a better hold upon the bags.

Both slat conveyors and continuous band conveyors are used for the conveying of bags in a horizontal plane. The band conveyor for bags is very similar to the band conveyor for bulk material, except that the idler rollers in the bag conveyor will be much more closely pitched. Loading chutes, ploughs and travelling trippers or throw-offs display a great similarity to those for bulk materials.

GRAVITY ROLLER CONVEYORS.

Gravity roller conveyors may be used for transporting bags, but the rollers should be very small in diameter and closely pitched—the angle of declination being about 5 degrees.

In considering the movement of bags, mention must be made of the tremendous amount of conveying that is done by the mill truck, and consideration should be given to conditions under which trucks are used. The use of a truck seems at first so obvious that students may be forgiven if they assume that.

having acquired a truck, all the conditions necessary to successful bag trucking are present. Such, however, is not the case, for apart from the fact that a glance at any truck maker's catalogue will embarrass the would-be truck user with the variety of designs offered, successful continuous trucking requires a suitable trucking surface. An untreated concrete surface vies with soft timber for being considered the worst possible surface upon which to wheel trucks. Concrete will dust and chip and soft timber will wear until the potholed and rutted surface makes continued trucking a feat of endurance, if not a positive menace. Many accidents have been caused by trucks being suddenly stopped or tipped through the wheels jamming or fouling irregularities in the floor. A concrete surface treated to prevent dusting is quite a good surface, if somewhat irresilient.

Timber floors with a good maple or other hard wood surface are expensive, but make a very good job, whilst disused conveyor banding laid along the regular truckways over timber or concrete takes a lot of wear, and provides a more resilient surface.

SACK CHUTES.

For the movement of bags from higher to lower levels, a variety of designs of chutes are used, from the straight floor to floor chutes and the "swift sure" floor to floor chutes to the single, double, or treble spiral chutes reaching all the floors of the mill or warehouse.

A simple straight chute inclined at a fairly flat angle is subject to the same objections as the inclined conveyor in that it occupies an unnecessarily large amount of floor space. The vertical "swift sure" floor to floor chute is an improvement upon this and in the chute shown in Fig. 51 it will be seen that there is a right angled bend at a point just higher than the height of a standing sack from each floor. These bends are used to decelerate the bag after it has fallen vertically from the floor above. This type of chute may be used to move bags from one floor to the floor immediately below, or by the opening of the trap doors shown bags can travel down through all the floors without interruptions. Where there is a constant demand for delivery of bags from an upper floor to the ground or near ground level, the chute may be made of a single straight drop with a properly designed curve at the bottom leading on to a horizontal tray.

It is claimed for the "swift sure" chute that in spite of its apparently drastic treatment of the packages being dropped, it does in fact handle them with remarkable gentleness, always provided that the chute is properly designed and constructed.

The spiral chute is probably the most popular chute for general purposes, lending itself both to floor to floor operation

and to the delivery of materials to transport vehicles. The illustrations of chutes are self-explanatory as far as operation is concerned. The chute itself may be built up from cast iron sections bolted together, but this makes an expensive and very heavy job, whereas the chute fabricated from dished steel sheets either by rivetting or welding is light in weight and economical

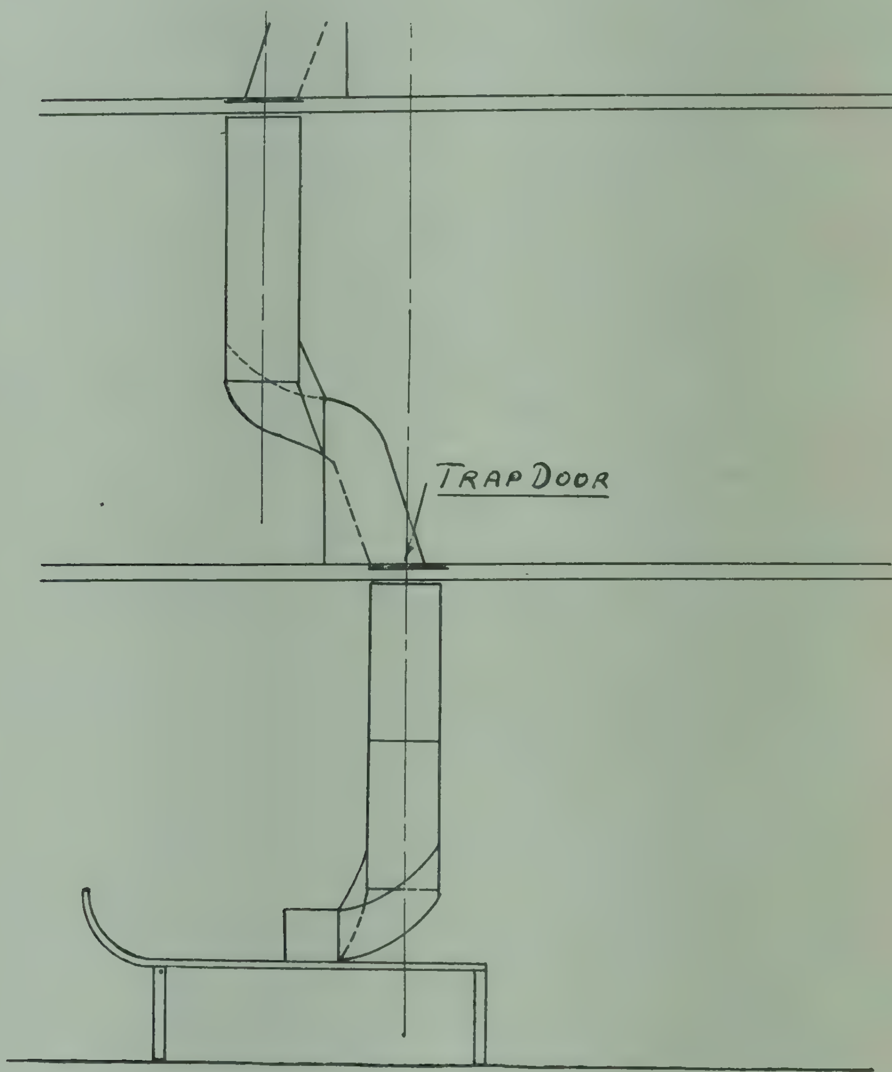


Fig. 57 **Swift Sure Floor to Floor Chute**

in cost, and as the wear is negligible, where a reasonable thickness of plate is used, a long life is obtained.

Where floor to floor operation is required, various methods of discharging from the spiral chute may be used. One method is to have a fairly elaborate take off chute permanently fixed at one end to the spiral and arranged to hinge up out of the way when not required (Fig. 58). A second method is to have the spiral constructed so that part of it hinges open (Fig. 59), and

the bag thrown out of the opening by a deflector plate set into the trough of the spiral.

A very cheap and increasingly popular practice is to use a simple, flat board, shaped at one end to fit snugly in the trough and arranged to carry the bag over the edge of the spiral at a lower point on to the floor. Treble spirals, due to the restricted head room, do not lend themselves to floor to floor operation.

For loading out to waiting vehicles, the spiral chute at its lower end may finish in a fixed flat table whose far end reaches the platform of the vehicle, or it may include a bend which carries the horizontal table along the face of the building or, alternatively, the horizontal table may be hinged in the manner shown in Fig. 60, in which the table projects

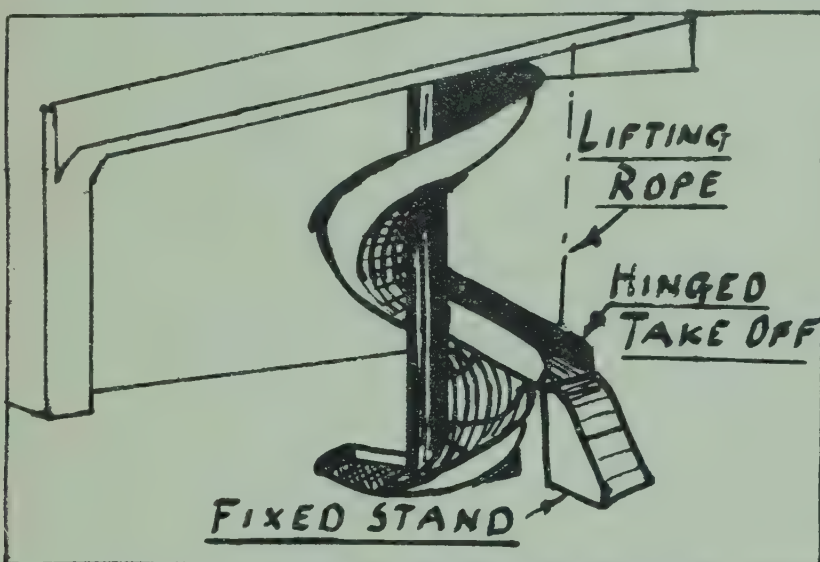


Fig. 58 Intermediate Discharge for Spiral Chute

over the cart in the working position and hinges up out of the way when not required. In order to facilitate manipulation, the hinged table is counterbalanced either by weighting the short end (Fig. 60) or by lifting weights attached by a cable to the tray as in Fig. 61. The table may be raised and lowered by manual effort applied direct to the table or through the intermediary of a simple winch as shown in Fig. 61, which illustrates the bottom of a double spiral chute arranged to deliver to both sides of a loading platform.

Chutes delivering bags to waiting vehicles may be fitted with automatic bag counters arranged so that each bag passing the counter strikes the flap connected to the counter which thereby registers the bag's passage. A more modern method of checking bags is afforded by the bag interrupting a ray of light shining across the chute on to a light sensitive cell which records the number of interruptions; with both these counters two or more bags passing in contact with each other will only

count as one bag and, therefore, neither of these methods of counting bags eliminates the need for a manual check of bags discharged to the vehicle.

Whilst these notes do not exhaust the possibilities of chutes as a means of lowering bagged materials, they should be sufficient to give a good indication of general practice.

STORAGE OF BAGGED MATERIALS

The bag storage of raw materials is still very widely practised in compound milling and lends itself to the flexible

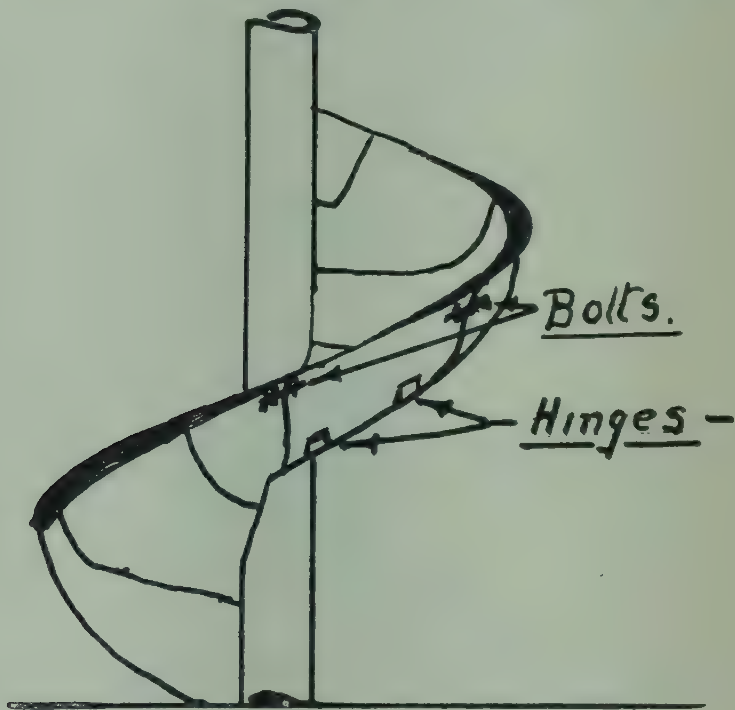


Fig. 59 Alternative Intermediate discharge

handling of a wide range of materials in parcels differing very greatly in size. The chief objection to bag storage is the excessive amount of handling involved, principally manual, with a resulting high cost. The merit of bag storage is instanced by the following features:

(1) Ease with which space allocated to different materials may be varied.
(2) The floor space could, if the necessity arose, be used for finished goods storage and vice versa.
(3) Material showing a tendency to "heat up" can be stacked loosely and in small piles, thus affording good control over dangerous material.

Where bag storage is used, the piles into which the bags are stacked should have a number of secondary passages between them as well as the main truckways. The height of the pile may be limited by the allowable weight per square foot of

floor area or, with light material, by the necessity of maintaining adequate clearance from sprinkler heads. The law requires that the safe floor load shall be prominently marked

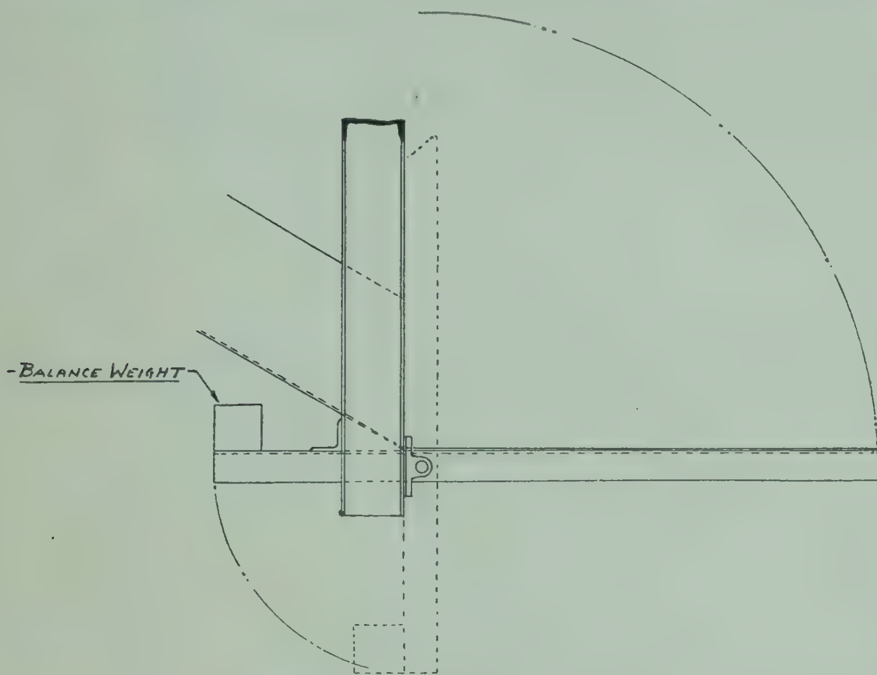


Fig. 60, Balanced Loading Out Table

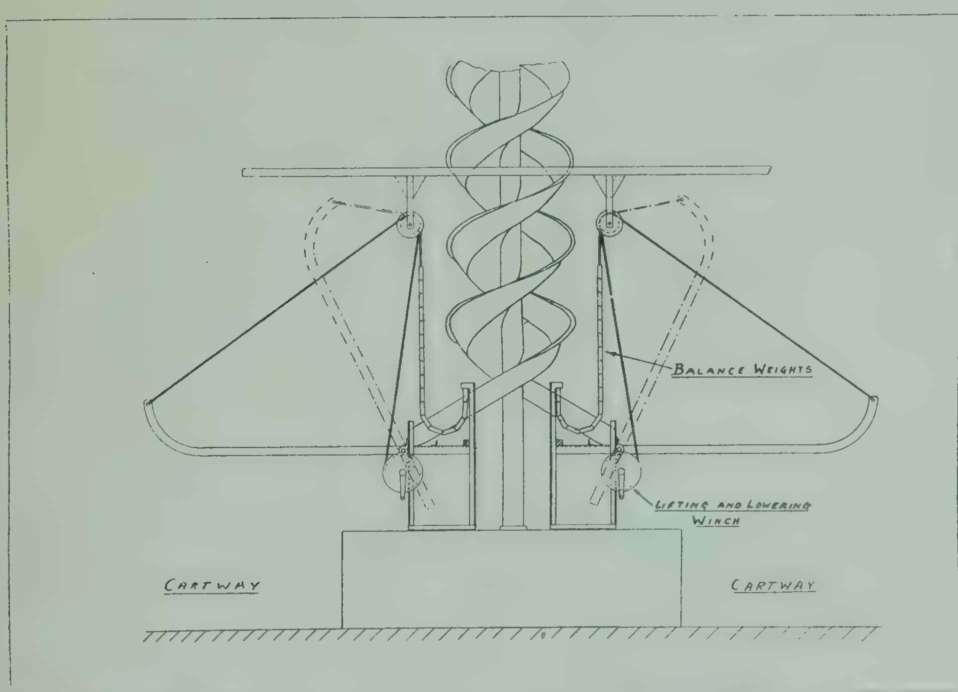


Fig. 61 Double Spiral Chute showing Loading Out Tables

on each floor of the warehouse in such a position as never to be hidden from view, and the wall adjacent to the doorway or the door itself is usually selected for the site of the floor loading figure. The construction of the building will clearly affect the

allowable floor loading, but this latter is not likely to be outside a range of from $1\frac{3}{4}$ cwt. to 3 cwt. per square foot. Clearance from sprinkler heads required by insurance companies is 12 inches.

Regular and tidy stacking of bag piles leads to ease of stock control and lends itself to the proper observation of rodent damage. With concrete floors it is good practice to stack the pile on a base of timber baulks so as to improve ventilation. Small piles are extravagant with floor space; very big piles are a source of fire risk and provide ideal homes for rats, so that the size of a pile for any particular material in a given circumstance is always a compromise. Damp and oily materials should always be stored in the smallest feasible piles to reduce risk of spontaneous combustion. A large pile can smoulder unnoticed for days and burst into flames upon being broken into. In lofty, single storey sheds with materials in good condition very big piles may be built and piles 30 feet and more in height are not unusual.

CHAPTER III.

ELEVATOR AND CONVEYOR CHAINS

In some mills the mill operatives have little interest in and no responsibility for the use of the various handling machine accessories like chains, buckets, conveyor belts, etc., the work being handled exclusively by the engineering department. In other mills, the men who look after chains, buckets and belts do not belong to the engineering department and are recruited from the ranks of the mill operatives who are responsible to the mill foreman.

In view of this and the fact that all mill workers ought to be reasonably familiar with such commonplace equipment, a fairly full reference is made to conveyor chains in the following.

Under this heading will be discussed those chains that are used to convey movement to the carriers of elevators, be they buckets, trays, scrapers, slats, etc. Those chains which are themselves the carriers of the conveyed materials will be considered later along with the machines of which they are part.

The most common chain fitted to conveying machinery is the pinless chain introduced by Wm. Ewart in 1873 and marketed in America by the Link Belt Co. of Chicago, and in England by Sir Francis Ley of Derby. This chain, known as the Ewart chain, is illustrated in Fig. 62, from which the simplicity of connecting a pair of links may be seen. The ability to connect link to link without the use of pins makes

the building up of any length of chain a matter of great convenience.

Each link consists of a malleable casting formed of two side bars, a tail bar and a hook bar. At the junction of one or both side bars with the tail bar, a flat or recess is formed allowing the hook of the mating link to be slid into position in the manner shown. This sliding action can only take place in

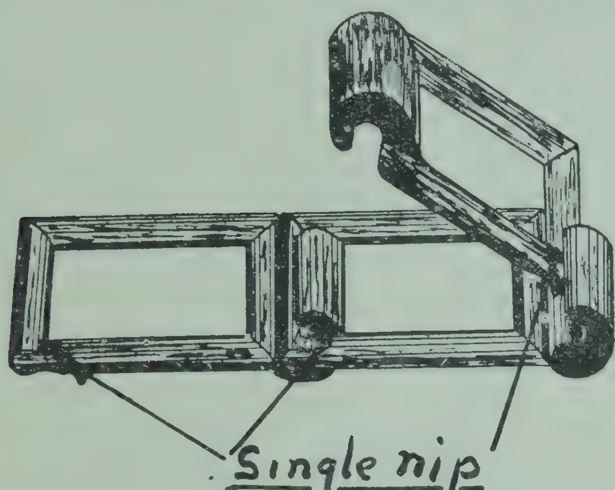


Fig. 62 Ewart Com on Chain Links

one relative position of the links and the links cannot slip apart when in the working position. With a recess or nip in one side bar only, the links can only be paired from one side whilst with links having a double nip the links may be fitted together from either side.

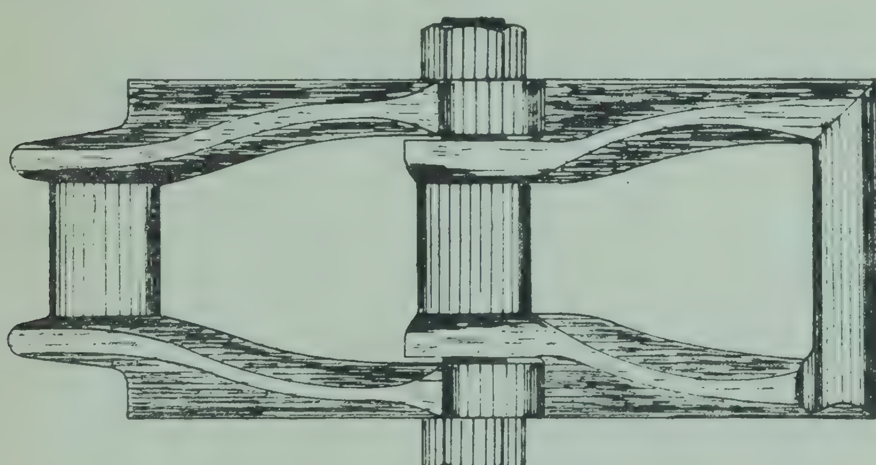


Fig. 63 Ewart Coupling Links

In a drive not having a jockey pulley or other tensioning device to take up the chain slack, it is almost essential to use a special pair of coupling links to couple the two ends of the complete chain. A pair of coupling links is shown in Fig. 63 and, as will be seen, the tail bar of one of the links is formed by a removable pin with the hook of the other link being closed,

forming a tubular bar through which the pin passes. In use, this chain will run without lubrication, although the life will naturally be shorter than with a lubricated chain.

The wheels used with the chain may be of normal cast iron or may be chilled castings which latter wear much longer. For special applications cast steel wheels may be used. It is often a great convenience to have chain wheels made in halves, thus simplifying the fitting or replacement of wheels, the halves of which may be placed over the shaft and bolted together. When correctly fitted, a chain and wheel assembly should appear as bearing on the back of the hook of the link with the hook opening away from the wheel.

When used in elevators and conveyors, the chains are fastened to the buckets, slats, or other carriers, and for this purpose special links known as attachment links are used. These attachment links in the case of a bucket elevator will be fitted into the chain at the distance apart it is required to have the buckets, and usually there will be three or more common in Fig. 64, i.e., with the tooth of the wheel driving the chain

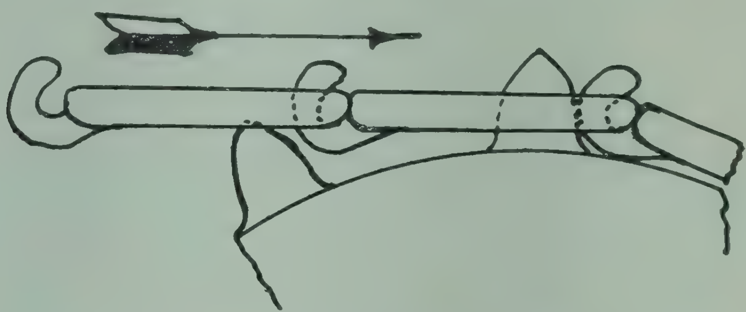


Fig. 64 Chain and Wheel Assembly

links to one attachment link, although in the case of the slat conveyor the chain may be composed entirely of attachment links.

The various sizes of Ewart chain links are differentiated by numbers: for instance, a No. 42 chain is approximately $1\frac{3}{8}$ in. pitch, whilst a No. 63 is 3 in. pitch. Similarly, attachment links are known by a letter and a number. Representative attachment links are shown in Fig. 65 with their code numbers and typical applications. Reference to a chain maker's catalogue will show that a large variety of different types of attachment links are stocked as standard.

Where a pair of chains are used in an elevator or a conveyor, it is usual to find that they are "matched" chains and this has to be borne in mind when making replacements. A slightly stronger chain than the Ewart is the "Pintle" chain whose links are joined by pins rivetted over or cottered (Fig. 66A). Rivetted pintle chains usually have connecting links every ten feet.

For larger elevators and conveyors, the Gray pin chain is frequently used (Fig. 66B). The links of this chain are fitted with renewable steel pins fitting tightly in the side bars of the links but not rivetted over. For use with abrasive materials,

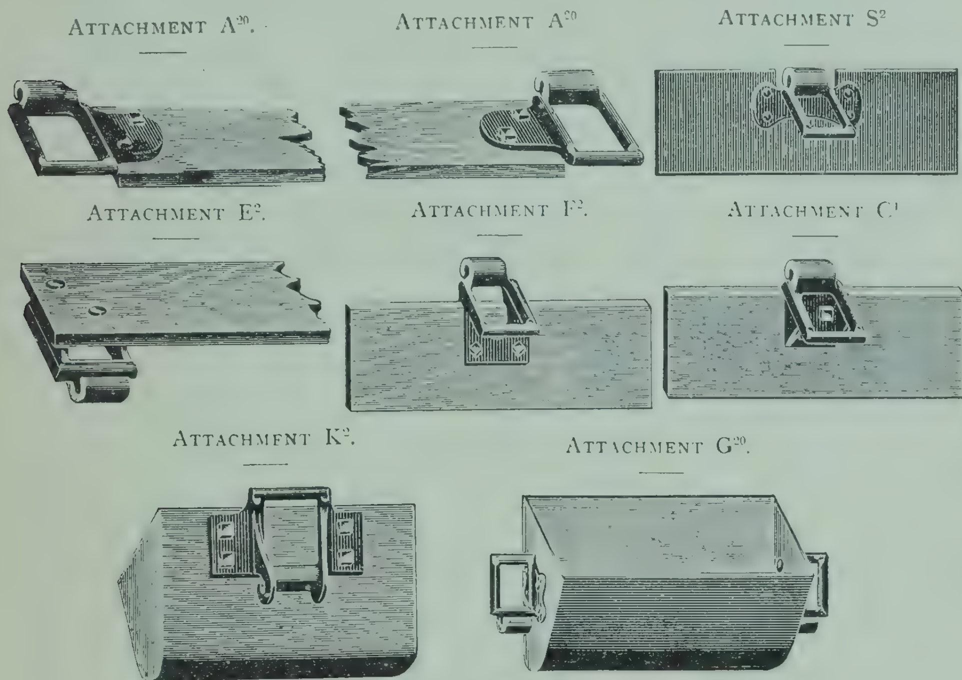


Fig. 65 Selection of Ewart Attachment Links

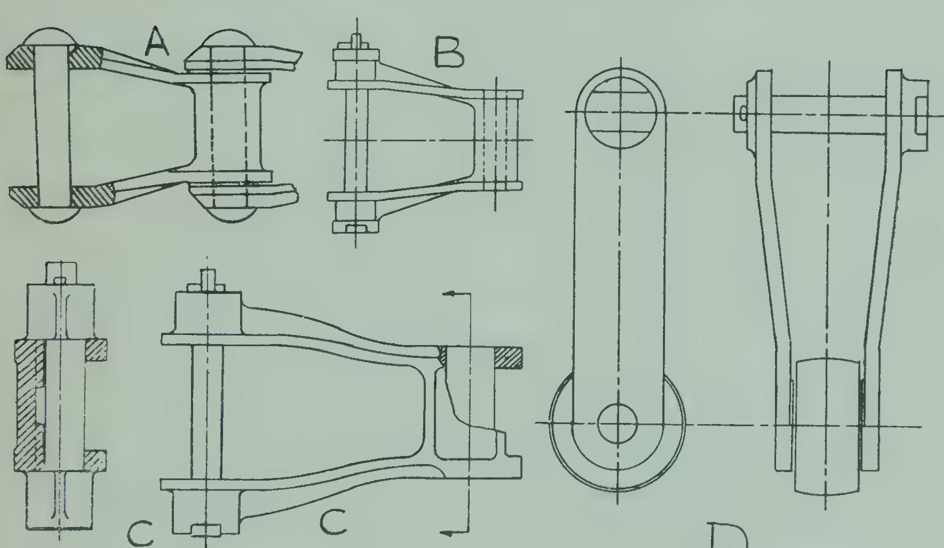


Fig. 66 (*a*) Pintle chain ; (*b*) Gray's Pin Chain ; (*c*) Ley Bush Chain ; (*d*) Ewart Roller Chain

the Ley bushed chain (Fig. 66C) is very suitable. In this chain the small end of each link is fitted with a renewable steel bush upon which the wheel teeth bear and through which the link pins run so that those parts subjected to wear are both renewable.

Roller chains may be of the Ewart malleable iron type or of the Renold and Coventry steel type. Roller chains generally are of the bush chain pattern with a freely revolving roller fitted over each bush. This type of chain is particularly suitable for long conveyors, the weight of the chain being taken by tracks upon which the rollers run.

The Ewart roller chain is illustrated in Fig. 66D and the Renold and Coventry chain in Fig. 67.

All the foregoing chains are made with a variety of attachment links.

Chain wheels should preferably have ten or more teeth and should never have less than seven, although with large wheels a long pitch chain is desirable to avoid an excessive number of teeth. With long pitch chains it is advisable to keep the chain speed as low as possible to avoid noisy operation.

For short pitch chains of the very light Ewart type chain, speeds up to 1,500 ft./min. may be used and for the heavy chains and Gray chains 600-1,000 ft./min. The Ewart detachable chain is suitable for working loads up to 1,200 lb. in good conditions, and loads between this and 3,000 lb. should be carried by Gray chain.

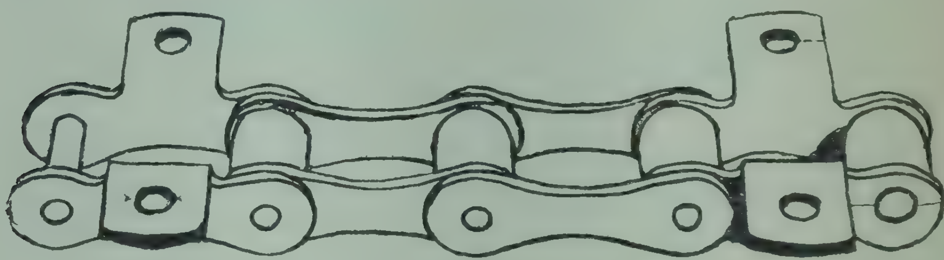


Fig. 67 **Coventry Steel Conveyor Chain**

Bush chains will handle loads up to 6 tons even in dirty conditions. The incidence of wear will cause the pitch of chain links to lengthen and when this becomes excessive the chain may ride the tops of the sprocket teeth and be torn asunder.

A practice recommended by the manufacturers of malleable chain is the filing or nicking of one or a pair of links, so that in the event of overloads, the weakened links will break before the rest of the chain becomes stretched out of pitch.

CHAPTER IV.

HANDLING PLANT FOR BULK MATERIALS

BELT CONVEYORS.

An outstanding characteristic of belt conveyors is the gentleness with which the conveyed material is handled compared with a worm or scraper conveyor. The principal part

of a belt conveyor is the belt which may be made of canvas, solid woven cotton, rubber impregnated cotton duck, balata, and in odd cases leather.

Balata belts are constructed of cotton duck impregnated with balata which is a true natural gum, stronger than rubber but not so elastic. The strength of balata belting, coupled with its limited stretch, makes it a particularly suitable belt for bucket elevators, although balata belts are rapidly being superceded by rubber and canvas belts.

Rubber and canvas belts are made from cotton duck impregnated with rubber. The method of construction is to impregnate the duck with rubber compound after which it is folded to the required size by mechanical means. The rubber cover is then put on and vulcanized. The thickness of the rubber covering on the pulling side of the belt is seldom varied, a thickness of 0.04 inch being common. On the conveying face of the belt, the thickness of rubber protection may be varied to suit different applications, but for most work a thickness of 0.06 inch is found satisfactory. It should be noted that it is the cotton duck which carries the power, the rubber being protection against wear. With particularly abrasive materials the stepped ply belt may be used in which a heavy thickness of rubber is to be found under the surface in contact with the conveyed material. Another feature of stepped conveyor belting is the greater flexibility in troughing.

CANVAS BELTS.

When used for conveyors and elevators, canvas belts are made from heavier duck than rubber and canvas belts. After stitching, the belts are treated with a waterproofing compound such as linseed oil, although this does not make them suitable for use under wet conditions but only helps to condition the canvas. After drying, the canvas belt is given a coat of mineral pigment which fills up the stitching holes as well as improving wearing qualities.

SOLID WOVEN BELTS.

These belts are used for light conveyors and they are loom woven their full width and not made up of plies. These belts stretch more than rubber and canvas, which is a disadvantage.

BELT FASTENERS.

Apart from the endless belts which are used in short conveyors and elevators, all belts have to be made up by joining the two ends of a straight length. Belt fasteners of a number of types are available and the user is well advised to follow the belt manufacturers' advice in the method of belt jointing he adopts. Typical methods of joining the two ends of a conveyor belt are shown in Figs. 68 and 69. Fig. 68 shows the alligator type

fastener which operates upon a hinge principle. Fig. 69 shows Bristol's belt lacing in which the flexibility necessary when turning the terminal pulleys is obtained by shaping the steel in a lace pattern. Both these types of fasteners are readily used by mill labour with a little practice.

Spliced as well as butt belt joints may be made, and spliced joints are usually cemented together and/or copper rivetted.

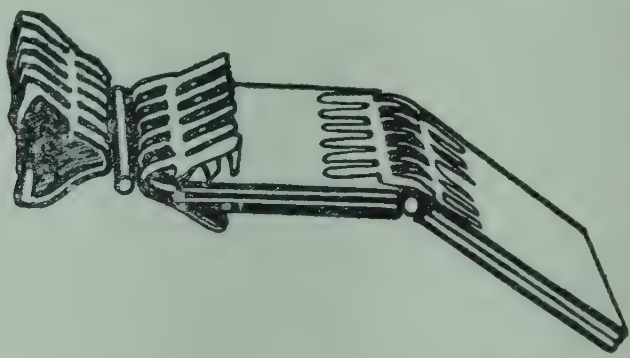


Fig. 68 **Alligator Flexible Belt Lacing**

The life of a conveyor belt may be shortened by :

(1) Using wrong type of belt for job.
(2) Carelessness when mounting the belt, causing injury to cover and edges.
(3) Joint not cut square, causing belt to run out of true.
(4) Use of side idlers to correct alignment of belt.
(5) Lack of lubrication, causing idler pulleys to bind.
(6) Carrier sets out of alignment.
(7) Too much sag between idlers, due to pitch of carriers being too large for weight of material carried.
(8) With rubber belts, oil or grease dropping on to belt and softening rubber.
(9) The diameters of the terminal, take up, snub or tripper pulleys too small for the thickness of the belt, tending to separate plies.
(10) Loading of material out of centre of the belt or directly over an idler pulley.
(11) Not feeding material in direction of travel and as near as possible to the speed of the band.
(12) Skirt boards set too low, thereby scraping and cutting belt.
(13) Excessive belt tension, causing belt stretch and tearing of joint.
(14) Insufficient belt tension, causing wear due to slip.
(15) Failure to prevent material spilling onto return flight of belt or to remove it before the belt reaches the terminal pulley to prevent crushing of the material between the belt and pulley.

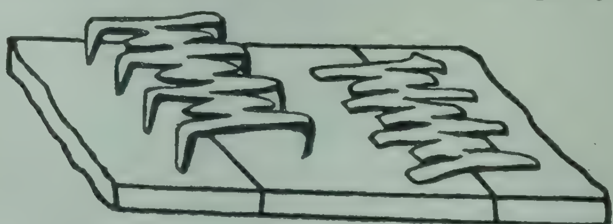


Fig. 69 **Bristol's Belt Lacing**

Belt life per ton of material carried will be higher if the belt is always run fully loaded.

When conveying a mixture of coarse and fine material, the use of a perforated feed shoe tends to protect the belt from the impact of lumps (Fig. 70). Belts should be stored in a place which is cool, dark and not too dry and should, if possible, be coiled on drums and covered with sacking. In the absence of drums the coil of belting should be wrapped in sacking and stood in a vertical position. When choosing a conveyor belt it should be remembered that too many plies cause the belt to run out of line and damage the edge against guide rollers, whilst too few plies where the belt is troughed tend to crease the belt down the centre, causing separation of plies.

Common practice is indicated in the following:

Belts	up to 14 in. wide	not less than	2	and	not more than	5	plies.
,,	from 14 in. to 22 in.	,, ,,	3	,,	,,	6	,,
,,	from 22 in. to 30 in.	,, ,,	4	,,	,,	7	,,

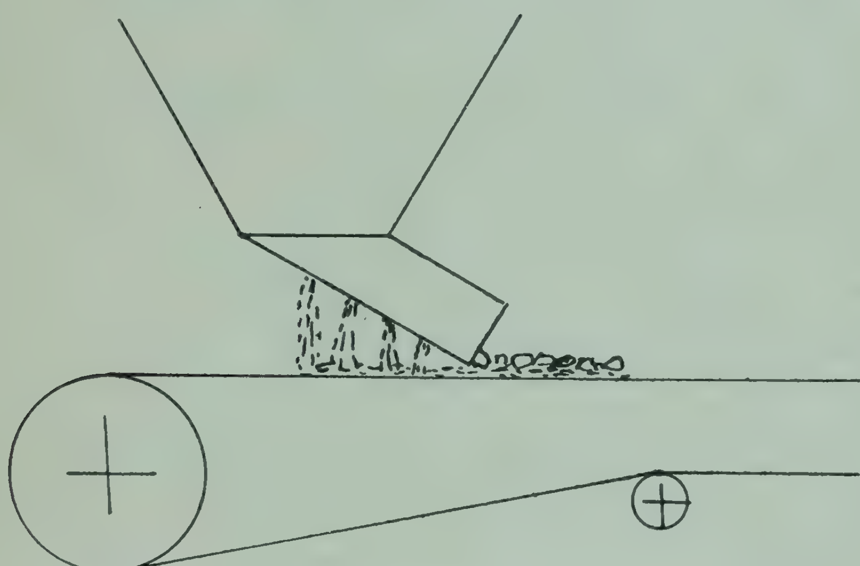


Fig. 70 **Perforated Feed Shoe**

The size of the terminal pulleys and snub or bending pulleys are influenced by the size of the belt necessary to carry the required quantity of material. It will be readily appreciated that, in rounding a pulley, the outer plies of a belt will be stretched more than those plies lying nearer to the pulley surface and that, therefore, a thick belt travelling round an undersized pulley will suffer more than when travelling round a large pulley. Practical experience with conveyors has resulted in certain sizes of pulley being specified for particular sizes of belts, and as has been noted previously, belt thickness is related to belt width and, therefore, in specifying a size of pulley for a width of belt, the thickness of the belt is automatically considered.

Thus, the following pulley sizes are commonly used with the corresponding widths :

Belt Width.		Pulley Diameter.
10 inches	... ...	10 to 14 inches
12 ,,	... ...	12 to 16 ,,
16 ,,	... ...	16 to 20 ,,
22 ,,	... ...	18 to 26 ,,
30 ,,	... ...	26 to 34 ,,

And as a result of similar considerations, bend or snub pulley diameters should be equal to :

$$\frac{\text{Number of belt plies} + \text{the width of the belt.}}{3}$$

The answer being expressed in inches.

Idler pulleys should be pitched for grain, oats, etc., as follows :

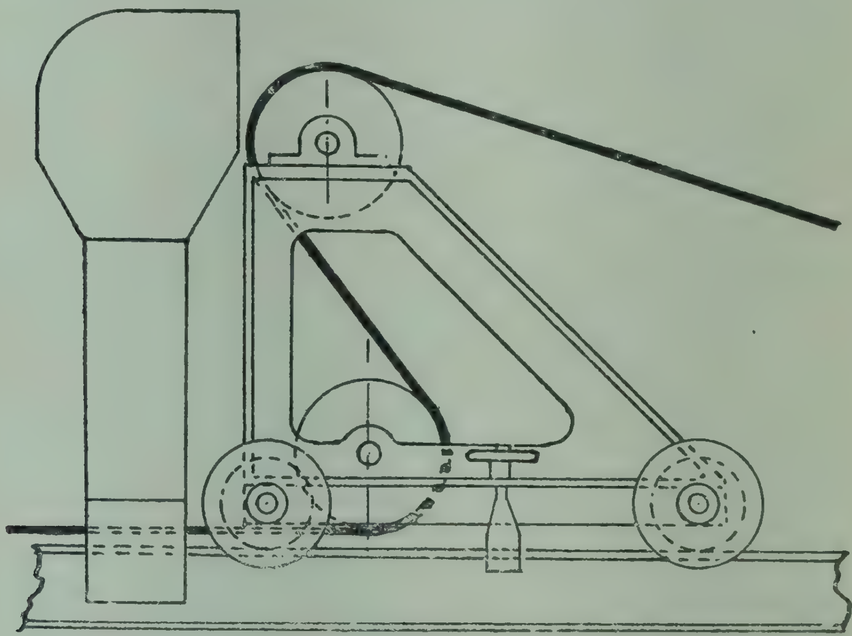


Fig. 71 Travelling Tripper

Belt Width.		Centre of Idlers.
18 inches	... ...	5½ feet
20 to 28 inches	... ...	5 ,,
30 to 38 inches	... ...	4½ ,,

Belt speeds for grain :

Belt Width.		Speed Ft./Min.
18 inches	... ...	300
24 ,,	... ...	350
30 ,,	... ...	400
36 ,,	... ...	450

Carrying capacity in bushels for a troughed belt may be roughly determined from the following expression :

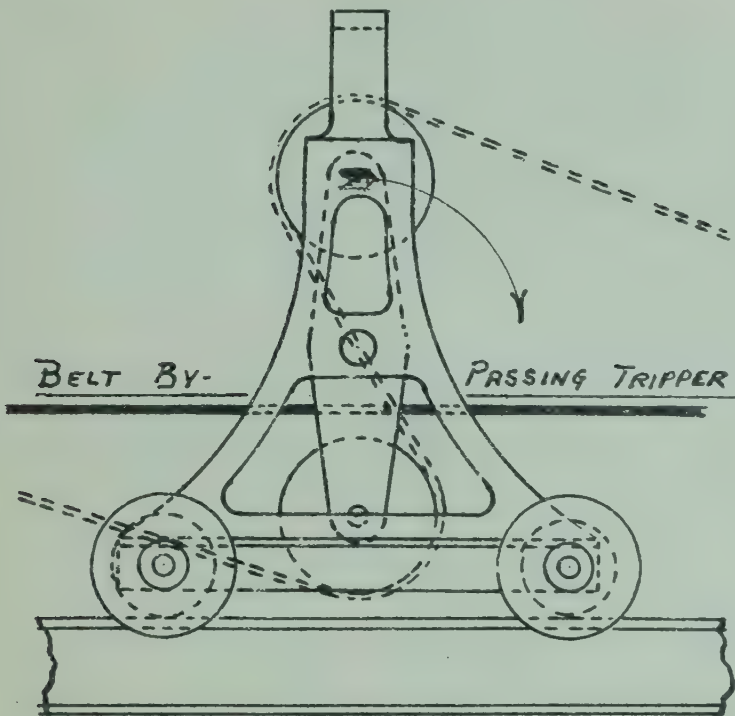


Fig. 72 Adjustable Pulley Tripper

Fig. 73 Reversible Tripper

Carrying capacity at 100 ft./min. belt speed $= 2\ W^2$ bushels,
and for flat belts $= 1.2\ W^2$ bushels.

Where " W " is the width of the belt in inches.

The discharging of belt conveyors at intermediate points is usually effected by a travelling tripper, the action of which may be seen in Fig. 71. This tripper is mounted on a track attached

to the conveyor structure and is usually moved from point to point by hand, being clamped in each position as required. Some trippers have the bending pulley spindles mounted between a pair of arms which are themselves pivoted in the tripper frame. This arrangement allows the bending rolls to be swung into the position shown in Fig. 72, where the belt and the conveyed material can travel uninterruptedly past the tripper, or the rolls may be moved into the position shown in Fig. 73, which position allows the tripper to discharge material from the belt if the conveyor is used in a reverse direction.

Where a tripper having adjustable pulleys is used, it is desirable to tension the conveyor belt automatically.

In the feeding of belt conveyors the chute or feed shoe should be arranged to direct the material on to the centre of the belt and should avoid material bouncing on the belt. Extended sides on feed shoes known as skirt boards are used to ensure proper centralization of the feed and the avoidance of direct drops on to the band should prevent bouncing.

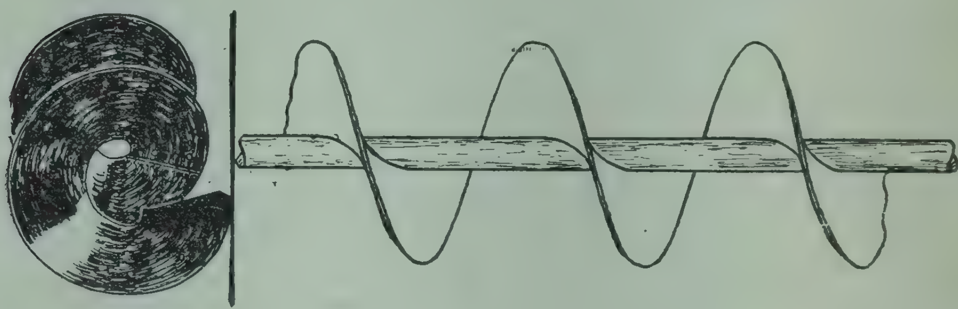


Fig. 74 *Fig. 75*

WORM CONVEYORS.

These are classified principally by the construction of the blades, and the four chief types are:

(1) Continuous full blade.
(2) Continuous spiral ribbon.
(3) Intermittent paddle blades.
(4) Intermittent crescent blade.

Types 1 and 2 may be made either right or left handed and, once constructed, cannot be altered, whereas types 3 and 4 are almost always adjustable both to angle and to hand.

A right handed worm is one which, when observed from one end of the worm, a clockwise direction of rotation brings the material towards the observer, and for left handed worms a clockwise rotation takes the material away from the observer.

Continuous full blades are usually stamped steel sections bolted, rivetted or welded together and fastened to the shaft at intervals, or the sections may be spot welded to the shaft with

or without being bolted. Fig. 74 shows an illustration of two stamped steel blades rivetted together, whilst Fig. 75 shows a complete worm shaft. This type of blade gives the most positive conveying action of all the various types of worms, and if the worm trough is completely enclosed and there is no pressure relief at the discharge end, should the discharge chute become blocked, the pressure built up will be sufficient to collapse the worm blades providing, of course, that the source of power does not cut out first.

This leads in practice to the provision of an emergency outlet at the extreme end of a worm trough, and this outlet may be unrestricted or may be closed by a loaded flap. Where it is necessary to continue the worm trough beyond the last outlet,

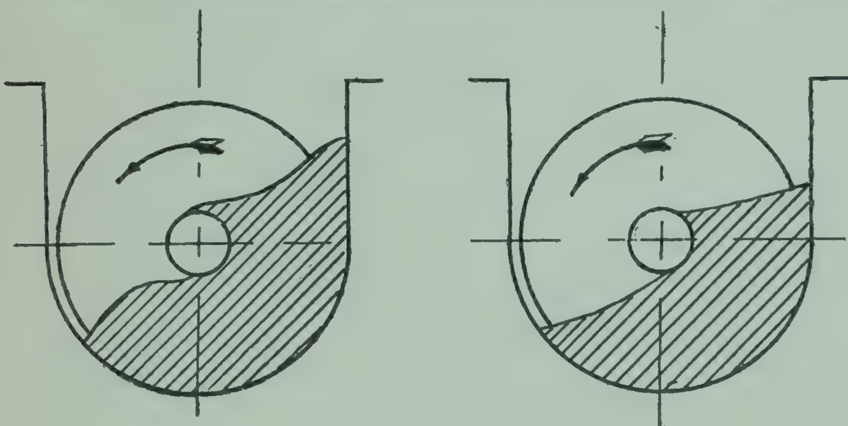


Fig. 76 45 % Loading 38 % Loading

it is usual to fit a blade of the opposite hand to the main worm in that part of the trough beyond the last outlet, to prevent the accumulation of meal in the dead end.

Average proportions for the worm itself usually give a pitch (the distance travelled by the blade in making one complete turn around the shaft) not greater than the diameter of the blades, although this may be varied to suit specific circumstances. A long pitch will give greater rate of flow, but this is limited by the incidence of slip between the blades and the material being conveyed, which is dependent upon the co-efficient of friction between the two. Where the worm has to convey up an incline, it is desirable to keep the pitch as short as possible, particularly if the incline should be greater than 20 degrees from the horizontal.

The mechanical efficiency of worm conveyors is affected by what is called the cross section loading or, more simply, the depth of the meal on the trough. The best conditions for efficiency are indicated by the following :

For light, fine, free flowing, non-abrasive materials, cross section loading should be 45 per cent. with material weighing 30/40 lb. per cubic foot. For materials weighing 40/50 lb. per

cubic foot and containing lumps mixed with fines, a figure of 38 per cent. is better. Fig. 76 illustrates these conditions and the percentage referred to is the ratio between the shaded area and the total area. The importance of this principle is indicated by the following, taken from actual practice. A worm conveyor conveying 10 tons per hour of material at a worm speed of 60 r.p.m. was driven by a $2\frac{1}{2}$ h.p. motor. Under these conditions the worm trough was nearly full and the operation was interfered with by the frequent tripping out of the electric motor. The speed of the worm was increased to 80 r.p.m., the same quantity of material being fed to it: this meant a very much reduced depth of meal in the trough. The same electric motor was used. The useful work remained the same, but the increased efficiency of the conveyor at the lighter cross section loading meant less power wasted and the saving was sufficient to allow the motor to work without interruption.

The discharge from a worm conveyor having a single delivery point can only be controlled by either a variable speed gear for the worm shaft or by controlling the feed. The use of a slide in

Fig. 77 Spiral Ribbon "Two-Start" Worm

the delivery chute is bad practice with continuous full bladed worms. For worm conveyors having a series of discharge points, any desired distribution of discharge over these points is readily obtained by the use of slides, except for the terminal discharge point which should always be unobstructed.

CONTINUOUS SPIRAL RIBBONS.

This type of worm blade is a continuous full blade with the greater part of the blade nearest to the shaft cut away, and Fig. 77 illustrates a spiral ribbon "two start" worm. The term "two start" or "double start" means that there are two separate ribbons wrapped round the shaft with half a pitch between them. This type of blade is very useful for the conveying of wet or sticky material and, should the discharge become blocked, the worm shaft will continue to rotate without doing any damage.

PADDLE BLADES.

These blades are fastened to a shaft by bolting through holes in the shaft spaced to accommodate three or four blades in each

pitch length of shaft. The crescent blade varies from the paddle blade, only in the shape of the conveying member. Both the ordinary paddle and crescent bladed worms have the useful feature of being easily made to convey in the opposite direction by altering the setting of the blades. Providing the paddles are not too tightly located, the pressure on the worm arising from a blockage in this type of conveyor will relieve itself by straightening out the blades until they have no conveying action, but simply turn through the body of the material.

Paddle blades are often used to break up meals that have become lumpy in store or by getting wet, and are often featured in mixing conveyors. With light, bulky materials, spillages often occur at shaft couplings and intermediate bearing hangers, and these latter should never be larger than is necessary to fulfil their object. Worm shafts are often lightened by being made hollow and tube shafting is particularly common where paddle blades are fitted.

Worm troughs, commonly of "U" form, may be made of cast-iron fabricated steel or timber with a semi-circular steel plate fitted, although a trough of completely circular cross sections is occasionally met with. Maximum speed for worm conveyors varies with the size of worm and nature of materials handled, but for compound milling materials a speed of 120 r.p.m. for a 4 inch worm to 75 r.p.m. for a 20 inch worm should be considered maxima.

Worm conveyors will handle a wide variety of materials, but where the material is lumpy, attention must be given to the worm diameter. For instance, a material consisting of all 1 inch lumps should be handled in a worm of not less than 10 inch and for, say, 3 inch lumps, a 20 inch worm is desirable.

SCRAPER CONVEYORS.

Known also as flight conveyors or push plate conveyors. Probably the principal use of these conveyors in present-day compound milling practice is as short discharge conveyors at the outlets of machines and bins, or incorporated as part of a machine as in a cooler for cooked meals. The scraper conveyor lends itself to discharge at any number of intermediate points as well as at the end.

Intermediate discharge is made possible by making the bottom of the trough to have sections which slide out, leaving gaps through which the conveyed material may be discharged. Conveyors of this type fitted with a single chain use the lower flight. Conveyors having two chains may have either or both flights used for conveying. Troughs may be of cast-iron, steel or timber, and may be fitted with easily renewable wearing plates on the bottom. A normal speed for scraper conveyors is 40 ft./min. and a wide variety of materials may be handled.

DRAG LINK CONVEYORS.

These conveyors are popularly associated with the name of Arnold Redler who did a great deal to develop them. The chief characteristics of drag link conveyors are their compactness, low power consumption, and the comparatively gentle handling of the conveyed material. The drag link conveyor is composed of an endless chain, with specially shaped links (Fig. 78), running in a trough and supported at each end on chain wheels (Fig. 79).

The conveying principle can be considered as the formation

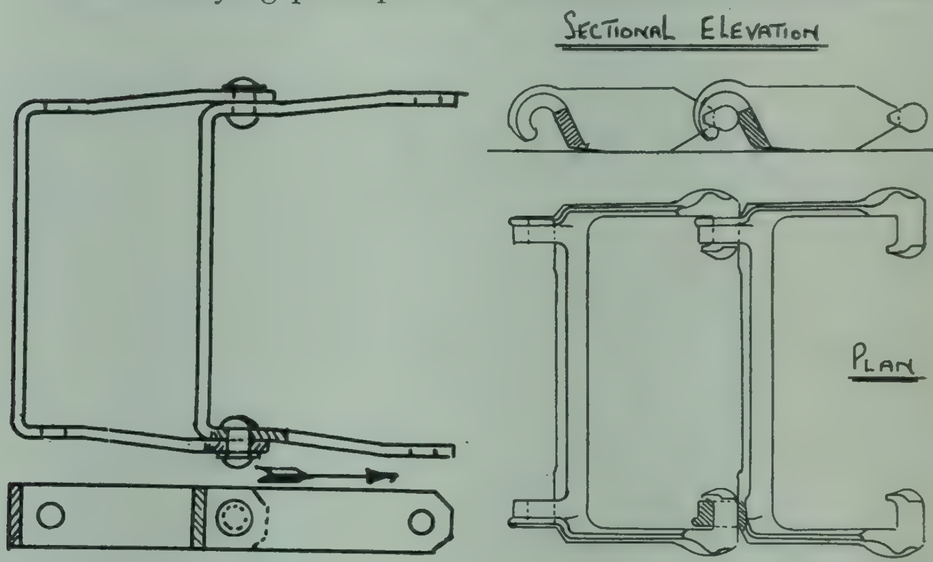


Fig. 78

"U" Link Steel Drag Link Chain Ewart Light Drag Link Chain

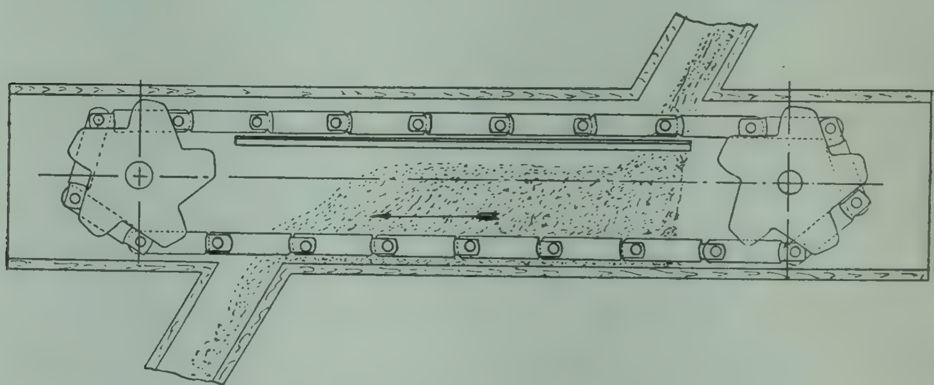
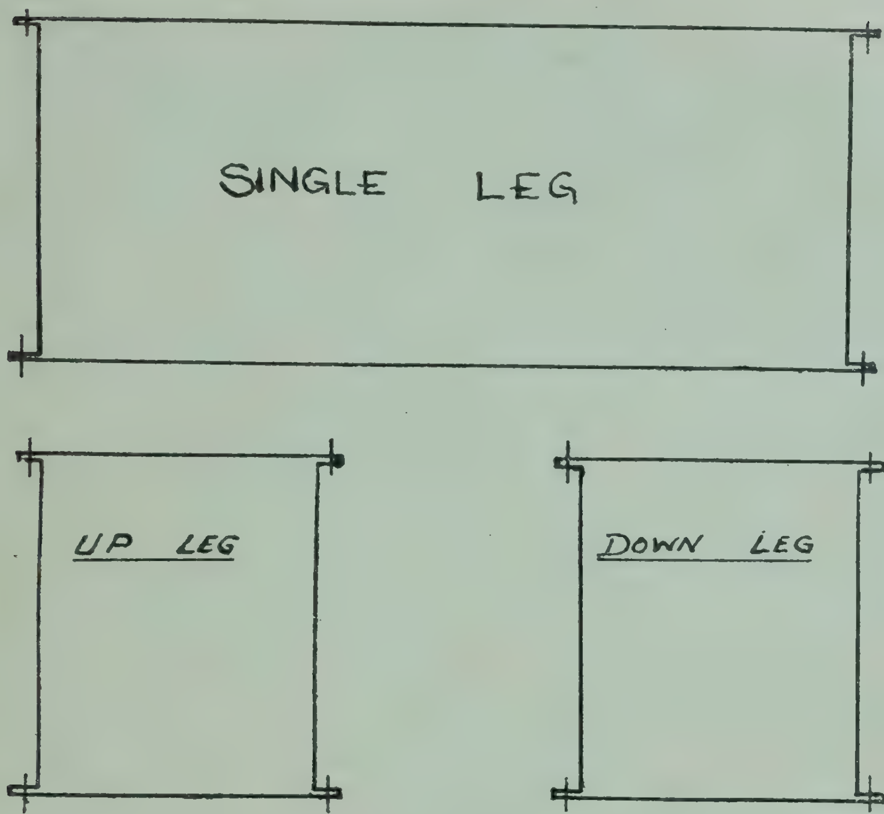


Fig. 79 Drag Link Conveyor

of a band by the filling of the spaces between the link members with some of the material to be conveyed, the rest of the material being supported upon this band. The depth of the conveying band may be as small as one-twentieth of the depth of the full load. The chain, when conveying, does not scrape along the bottom of the trough, but floats on a thin layer of material. The maximum speed of the chain is about 60 ft./min. and an average speed about 40 ft./min.



Double Leg

Fig. 80 Plan Section of Elevator Legs

The depth of material conveyed is equal to the width of the chain, i.e., a 6 inch chain will carry a 6 inch deep load, from which the carrying capacity of any size of chain may easily be calculated for any given speed.

> Carrying capacity in cubic ft./min. $= W^2 \times S$, where W = width of chain in ft., and S = speed of chain in ft./min.

To convert this to lb., it is only necessary to multiply by the weight per cubic foot of the material being conveyed. The standard drag link conveyor may be used up slight inclines, but for angles over about 25 degrees, special chains should be used.

The drag link conveyor may be made to carry material on both top and bottom flights where circumstances require, but if material is to be conveyed in one direction only, the bottom flight is used, the material being fed through the links of the return flight.

The drag link conveyor is particularly suitable for handling material of small and consistent particle size, like grain or meal, but would not be considered to be effective for materials like locust beans or expeller curves.

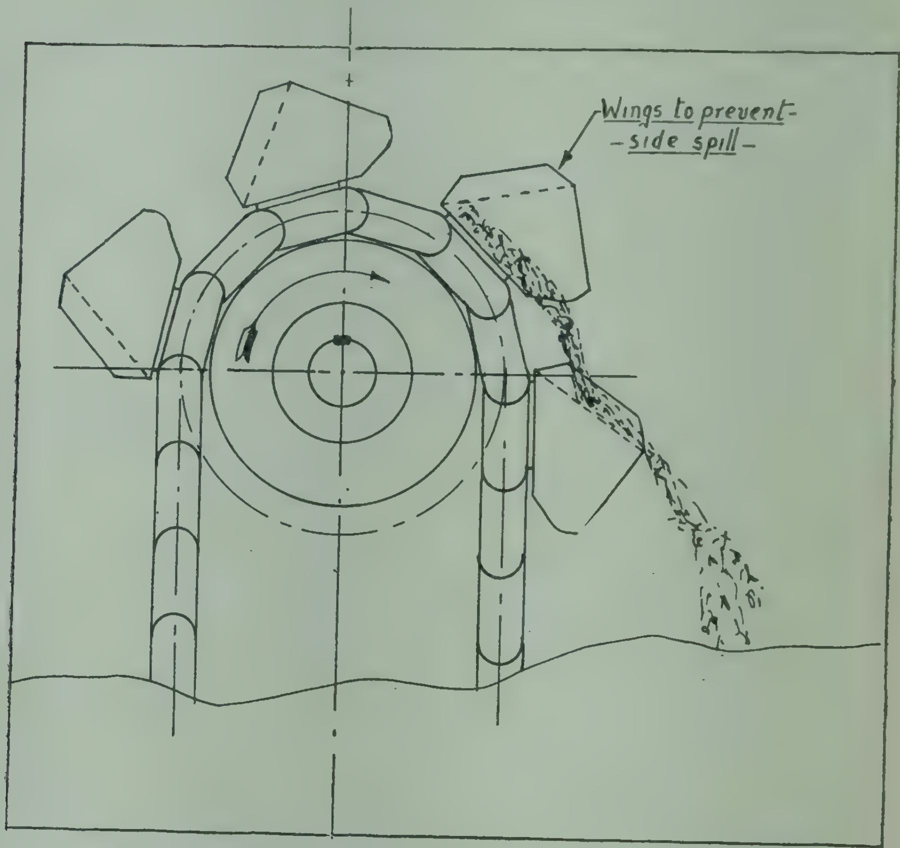


Fig. 81 Slow Speed Elevator

CHAIN AND BUCKET ELEVATORS.

The chains used in this type of elevator have been described previously, and the method of fastening the buckets on to the attachment links has been referred to. The difficulty of maintaining accurate matching of chains in double chain elevators makes it preferable to use two single chain elevators to do the work of one double chain elevator. The majority of elevator casings are fabricated from steel sheet and may be single or double legged (Fig. 80). Whichever type of leg is used there should be adequate bucket clearance and the position of the discharge opening should be carefully fixed, as a fault here may result in a part of the elevated material spilling down the return leg, thus reducing the effective capacity of the elevator.

Elevator dynamics require high chain speeds for satisfactory delivery of light materials, but high chain speeds have a number of disadvantages associated with them, the chief one of which is the wind or draught created by the rapidly moving buckets. This air movement tends to retard the feed into the elevator as well as causing the spread of dust. In view of this, there is a tendency to-day to use low chain speeds in bucket elevators in spite of the increase in bucket size necessary to handle the same quantity of material. Low chain speeds require that special

precautions be taken to ensure satisfactory bucket discharge, and this may be obtained by keeping the throat of the discharge chute well below the headshaft and using the back of one bucket as a chute for the material leaving the following bucket. Fig. 81 shows this action in an elevator having a chain speed of 100 ft./min.

The shape of elevator buckets depends to a large extent upon the nature of the material they are to handle, and Fig. 82 gives some typical examples. All the buckets shown in Fig. 82 are for use in elevators having fully centrifugal discharge.

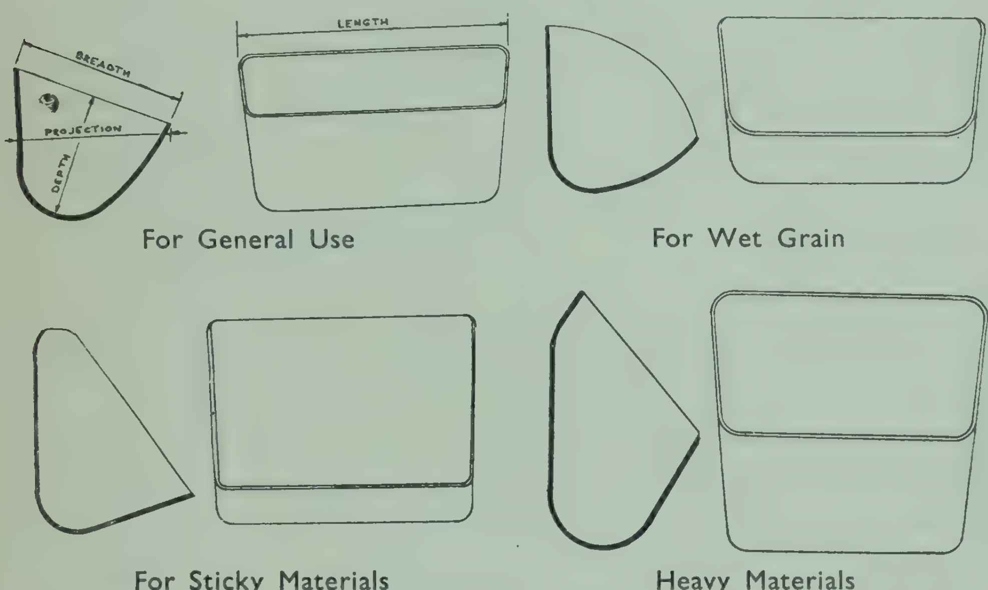


Fig. 82 Elevator Bucket Types

BELT AND BUCKET ELEVATORS.

Construction is generally similar to that of the chain and bucket elevator except, of course, that the chain sprockets are replaced by belt pulley and the chain by a belt.

Where the material is dry and free flowing, a solid woven cotton belt can be quite satisfactory, but for elevating material which is abrasive or damp, a ply belt is used. For wet grain elevating, a rubber covering of one-sixteenth inch on both sides of the belt is common practice. On the bucket side of the belt the rubber acts as a cushion, and on the pulley side of the belt a reasonable thickness of rubber over one-sixteenth inch will allow the bucket bolts to sink into the belt until their projection becomes negligible.

The width of the pulleys should be at least one inch more than the width of the belt, and the bucket width should be one to two inches less than that of the belt. As in conveyor work, pulley diameters should be as large as the circumstances will permit, and a recognized relationship between pulley diameter and belt plys is five inches of pulley diameter to one ply of belt.

In fitting buckets on to an elevator, it is sometimes advisable to insert a piece of old belting between the bucket and the belt to prevent the edges of the bucket bolt hole from cutting into the belt.

There is little doubt that where circumstances permit, the use of a belt to carry elevator buckets is preferable to a chain, but belting materials are subject to attack when handling oily or wet substances, and this has to be reckoned with.

The head or driving pulley of an elevator often has a crowned face for wide belts, and it is then advantageous to use two rows of buckets in " staggered " formation which helps the belt to conform to the pulley crown. A crown faced pulley is one whose diameter increases progressively from one edge to the centre and reduces back to the original diameter as the opposite edge is reached.

ELEVATOR CAPACITY.

The capacity of an elevator is governed by a variety of factors amongst which the more important are:

(1) The size of the buckets.
(2) The pitch of the buckets, i.e., the distance between them.
(3) The speed of the buckets.

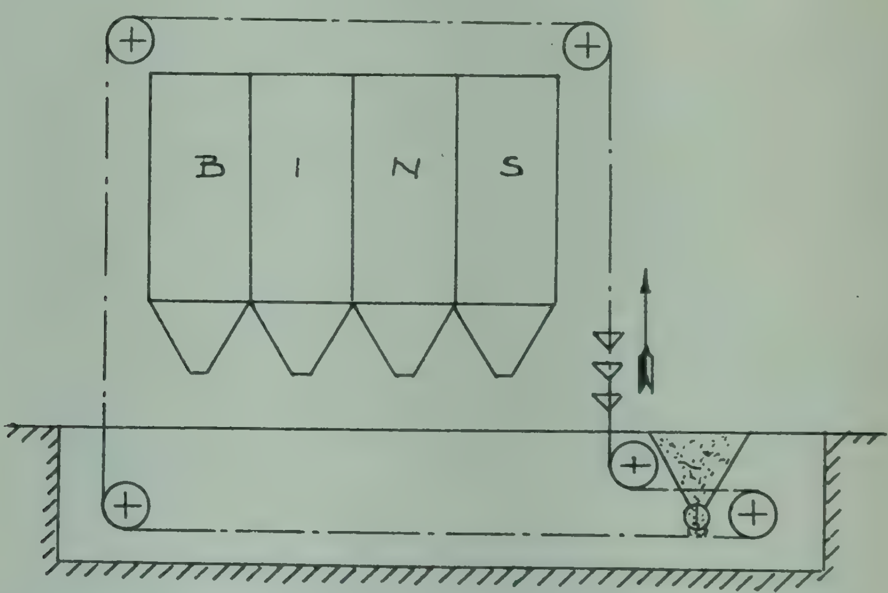


Fig. 83 Layout of Gravity Bucket Conveyor

All the foregoing factors affect the volume swept out by the buckets, but unless all the available bucket space is fully utilized, the actual carrying capacity may be considerably less and will be influenced by:

(1) The particle size of the material. Small pieces will pack better than larger pieces.
(2) Steadiness of feed to ensure all buckets being filled.
(3) Condition of material, whether damp or sticky.

(4) Shape of the buckets, whether suited to the material being handled.
(5) Density of the material.

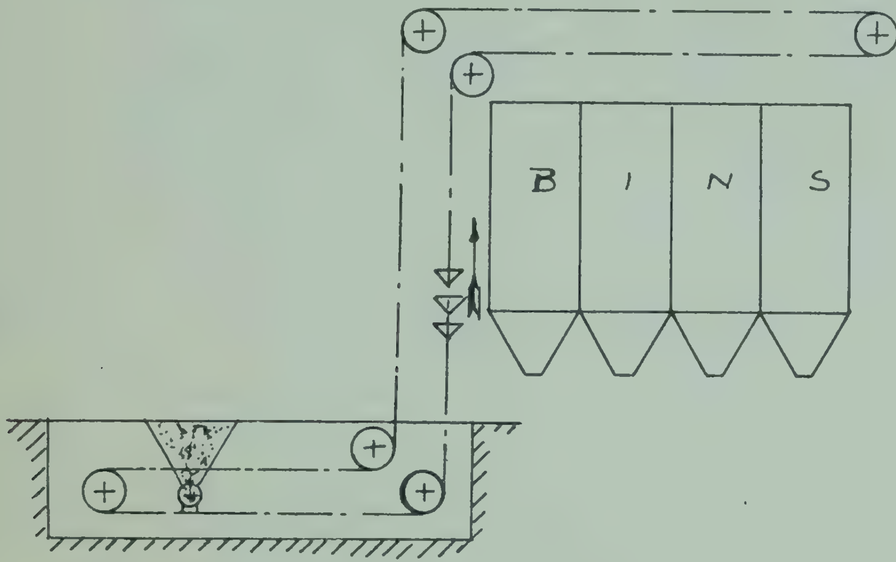


Fig. 84 Alternative Layout.

When all these factors have been considered, it still remains to ensure satisfactory design to enable the elevator to operate at maximum capacity; for example, faulty design may result in elevated material being spilled down the return leg. Finally, the neglect of cleaning may result in an elevator losing capacity due to the adhering of material to the inside of the buckets.

Assuming that working conditions are reasonably good, the capacity of an elevator may be determined from the following:

$$\text{Capacity in lb./min.} = \frac{\text{Bucket capacity in lb.} \times \text{belt speed in ft./min.}}{\text{Bucket spacing in ft.}}$$

This will yield a maximum figure which may need reducing sometimes as much as 50 per cent.

ELEVATOR-CONVEYORS.

The chief representatives of this type of plant are the gravity bucket elevator and the Redler elevator. The characteristics of the type is a combined horizontal and vertical transportation of material in one continuous operation carried out by one piece of apparatus. That part of the travel which elevates the conveyed material may not, of course, be actually vertical, but may be inclined at any angle between the horizontal and the vertical, but it should be noted that a handling system which could not be adapted to elevate vertically and convey horizontally on the one carrying member is not classed as an elevator-conveyor. For example, a band conveyor might convey for part of its length up an incline, say, 15°, and horizontally

for the remainder of its length, but this does not qualify it as an elevator conveyor, for under no circumstances could it elevate vertically.

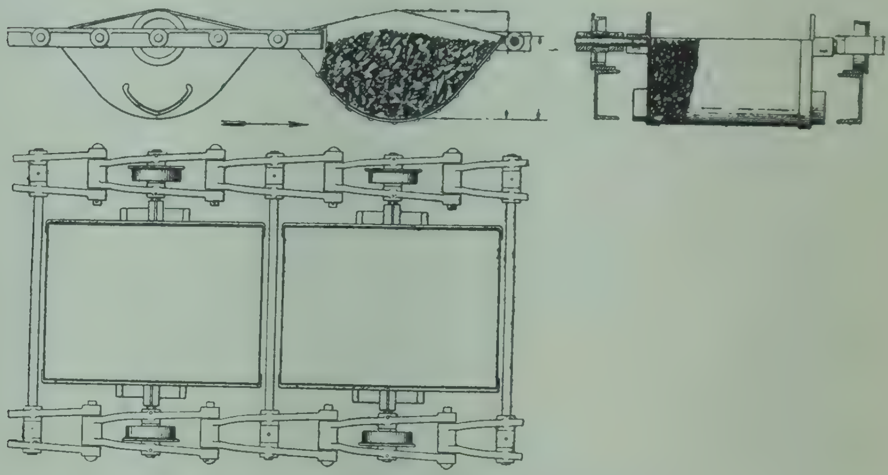


Fig. 85 Arrangement of Gravity Buckets

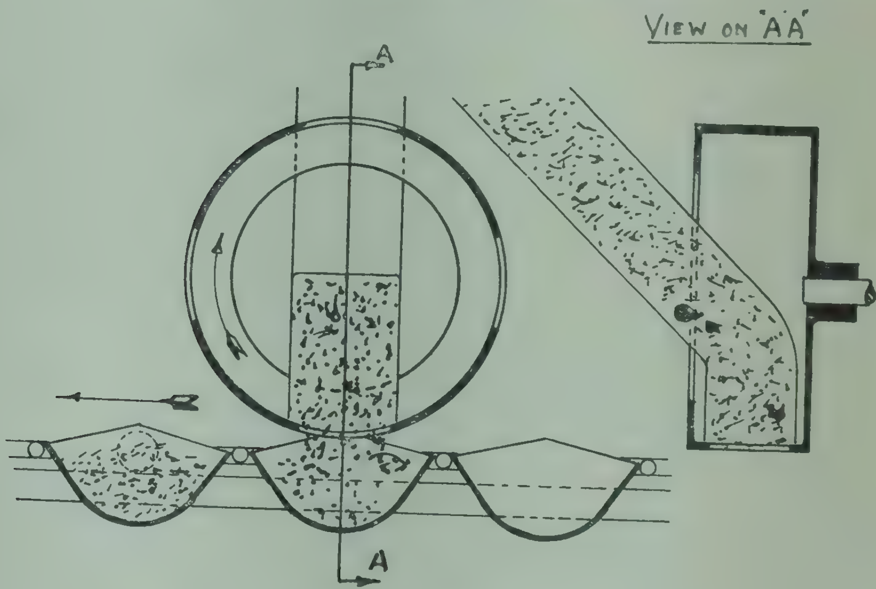


Fig. 86 Rotary Feeder

GRAVITY BUCKET ELEVATORS.

If the trays of a swing tray elevator were replaced by swinging buckets and the return leg moved a considerable distance from the up leg so that the chain and buckets in moving from the top of the up leg to the top of the down leg had to traverse some distance horizontally, a fair picture of a gravity bucket conveyor would be obtained. It is necessary, however, to add that the contents of the buckets are emptied by arranging for the buckets to be tipped during the horizontal part of their travel between the top of the up leg and the top of the return leg. The feeding of the buckets is also arranged during the horizontal movement of the buckets, this time between the

bottom of the down leg and the bottom of the up leg. Figs. 83 and 84 show typical layouts for a gravity bucket elevator and should be compared with Fig. 70 in the First Year text book. In the first case, the buckets simply travel round the bins which they are feeding and the bucket path is offset at the feed point. Fig. 84 shows a gravity bucket conveyor arranged for intake, but the need for space underneath the bins is avoided by returning the buckets down the same side of the bins as that which they ascend. Fig. 85 shows a typical arrangement of buckets and chain, from which it will be seen that there is a gap between

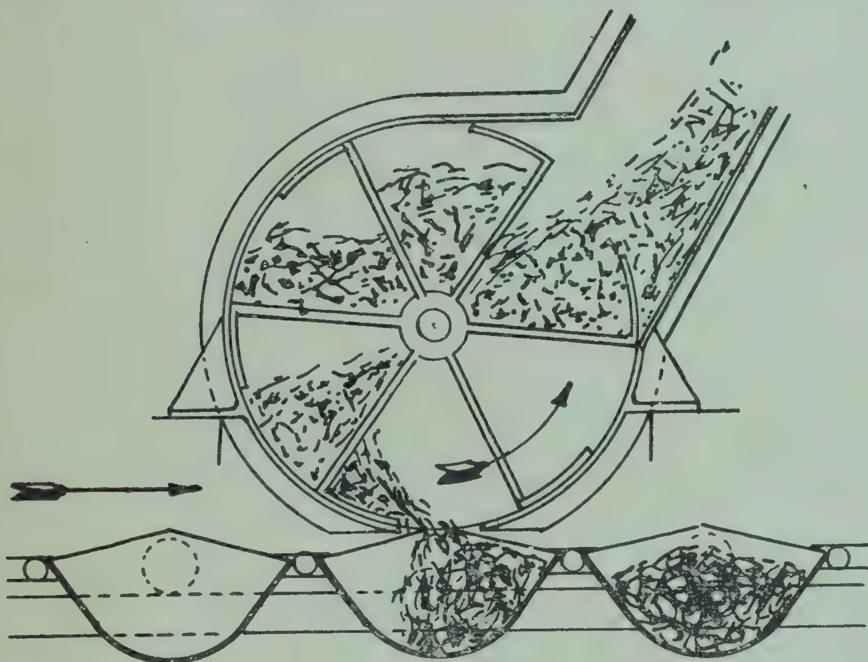


Fig. 87 Fan Type Feeder

each pair of adjacent buckets. The presence of this gap makes it necessary to interrupt the flow of material feeding the buckets to avoid spilling. The deposit of just sufficient meal to feed each bucket as it passes the feed point and the interruption of the feed flow between buckets may be arranged in a number of ways, but the use of a rotary feed is most common. Two types of rotary feeders are shown in Figs. 86 and 87. The action of the bladed rotor is fairly obvious from Fig. 87, the curved extension on the end of each blade will close the exit aperture during the time that the gap between a pair of buckets is passing under the feed point. In the feeder shown in Fig. 86, the cylinder itself revolves, and by virtue of the openings or ports in the circumference, uncovers the end of the feed chute at regular intervals.

It will be realized, of course, that the speed of the rotor will be synchronized with the speed of the buckets, but it should also be noted the rotor may be slowed down so that it feeds

every second, third or fourth bucket, in which case a number of bucket fillers would be used to fill the buckets with a number of different materials consecutively so that starting at one bucket filled with material A, the next bucket would be filled with material B, and a third bucket with material C, returning to material A for the fourth bucket, and in this way, every third bucket would contain the same kind of material.

In this way, the one conveyor may be used to carry three different materials simultaneously. The tipping of the buckets to discharge their contents is effected by curved adjustable trippers interfering with cams or projections mounted on or forming part of the buckets. The selective tipping of any particular series of buckets is made possible by having the cams on the different series of buckets made so that they travel along different paths and thus a tripper, set in the path of a particular series of cams, will only tip the buckets whose cams follow that path and will not interfere with buckets whose cams are otherwise located. For example, the three series of buckets referred to as being filled with different materials might have cams arranged as follows : No. 1 bucket close to the bucket end plate on the right-hand side, bucket No. 2 set off from the bucket right-hand side end plate, No. 3 close to the bucket left-hand side end plate. The trippers which interfere with the bucket cams may be mounted on the conveyor structure or may be mounted on the bin structure, and in all cases they can be swung out of the way when not required. It will be appreciated that the number of different materials that may be carried is limited only by the number of buckets in the conveyor and practicability of arranging sufficient different bucket cam paths.

The buckets are commonly made of cast-iron, but an alternative is to have cast end plates with the intermediate plate of steel which allows the same casting to be used for a variety of bucket sizes, the variation in size being obtained by fitting longer or shorter mild steel intermediate plates.

To avoid having gaps between buckets, they may be made with lips which project over the space between the buckets and are made to overlap one with another. With overlapping buckets, however, special precautions have to be taken to ensure that the buckets' lips overlap each other in such a way as to avoid "interference" when turning the sprocket wheels. Correct overlapping may be obtained by having a tilting block fitted near the bottom sprocket on the return leg, or the buckets, instead of being fitted directly to the chain, may be fitted on short arms in such a manner that the bucket trunnion is always about 6 ins. behind the chain pin. This feature causes the bucket path when turning the sprockets to be of greater diameter than the chain path, thus increasing the space between consecutive buckets to such an extent that the projecting lips are

clear of each other. A conveyor designed on these lines is called a Peck Carrier after the man who originated it. The usual speed of gravity bucket elevators is about 40 ft/min.

The slow speed of the gravity bucket elevator makes it unnecessary to enclose the bucket path in a casing, a feature which makes a useful contribution to the prevention of dust explosions. The operation of a gravity bucket elevator, whilst very simple, requires that care be taken to ensure that the proper trippers are set for dumping, particularly where the elevator is handling a variety of commodities simultaneously, otherwise materials that are intended to be kept separate may become hopelessly mixed.

Redler Elevator

This conveyor-elevator is a logical development of the drag link conveyor and utilizes the mass flow principle in the elevating of materials. The design of link for this purpose is somewhat different from that for horizontal conveying, and is seen in the diagram of the Redler elevator (Fig. 88). Experience has shown that the patented H. type flights will move the mass of material rather than drag through it. When elevating, the material may either be discharged from the top of the elevator or from any intermediate point by removing part of the elevator leg plate on one side. The design of chain link coupling allows the chain to turn both horizontally and vertically so that quite a tortuous path may be followed. Apart from these features, the characteristics of the Redler conveyor-elevator are similar to those of a drag link conveyor in that the chain speed averages about 40 to 60 feet per minute, the conveyed material is handled gently and the handling machine occupies a minimum amount of space.

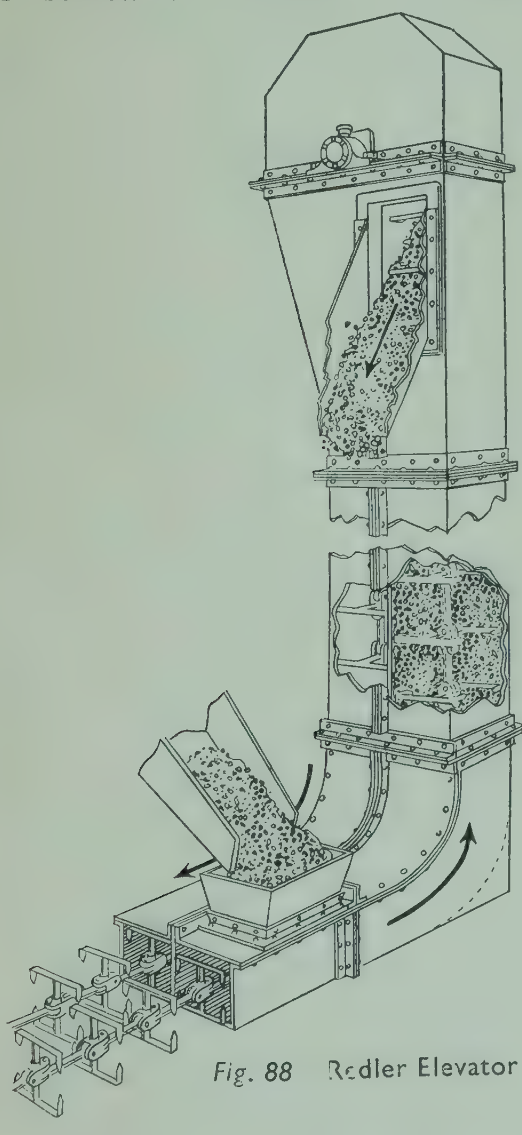


Fig. 88 Redler Elevator

Pneumatic Conveyor—Blowing Type

The use of blowing as a separate materials handling operation has never been widely resorted to for a number of reasons, amongst which is the high power required by fans and blowers compared with the power required by bucket elevators and also, of course, the fact that the laws governing this form of conveying have not been widely understood.

Even to-day, considerable differences are likely to be found in specifications from different designers for the same job, although the growing practice of using grinding machines having fan delivery of ground materials is providing a lot of useful information. The probability is that the majority of blowing systems installed in this country are of the low pressure type in which the air is moved by fans, but one or two installations use high pressure air from turbo blowers.

The most critical characteristic of a blowing system is the air velocity, and this varies within a range of from 3,000 to 6,000 ft. per min., depending chiefly upon the particle size and density of the material to be conveyed. The effect of any particular air velocity upon given material may be observed by arranging for a sample of the material to be suspended upon an open gauze floor located in a transparent tube through which air streams of controlled velocity can be passed. That air velocity which just supports the material particles is known as the critical velocity, and whilst this value may be obtained experimentally in the manner indicated, one authority quotes the following equation as yielding the critical velocity for a material of known specific gravity and particle size.

$$V = 3{,}280 \sqrt{d \times \text{Sp. Gr.}}$$

Where V = critical velocity in feet per minute
d = least diameter in inches.
Sp. Gr. = specific gravity which is the actual relative density and not determined from the weight per cubic ft. of the loose material.

For compound milling materials, the critical velocities are probably best obtained experimentally, and for grain, the average critical velocity is probably about 2,000 ft. per min.

It has been suggested that a suitable operating velocity is about $2\frac{1}{2}$ times the critical velocity, which gives about 5,000 ft./min. for grain. Two other factors which need to be considered are the volume of air required per pound of material elevated and the frictional resistance set up by the passage of air and material along the air tubes. An average figure for air volume can be taken as 50 cub. ft. per pound of material, although this increases with light, fluffy materials and is reduced with heavier materials. In actual practice, the conveyed material may be fed in through the fan inlet as in the discharge

fans of hammer mills, or the material may be fed into the moving air stream through a rotary seal or through a "Venturi" tube. The feeding of material through the fan, whilst sometimes very convenient, causes heavy wear on the fan blades and casing, for which reason the practice is to be avoided if possible.

Where the material to be conveyed is fed into the fan inlet, it is essential to avoid air starvation, i.e., a heavy feed that reduced the air inlet to very small proportions would reduce the conveying capacity unless a secondary unrestricted air supply to the fan was provided. This principle has been met previously in the suction nozzle of the pneumatic suction intake plants.

The effect upon a fan caused by the blocking of the outlet is not always readily appreciated, as it differs from the effect of blocking the outlet of a positive displacement machine. If a valve in a delivery pipe from a reciprocating pump, for instance, were to be shut, a pressure would be set up sufficient either to stop the pump or fracture some part of the installation; a blockage in a fan delivery, however, immediately takes load off the fan which, as a result, races in the contained air. Turbo blowers, however, operate as positive displacement machines. It will be appreciated that the exhausted side of a pneumatic conveying system should allow the minimum interruption to the discharge of air consistent with adequate separation of dust and bag filters used for dust collectors should be regularly cleaned.

It may be noted that the volume of air delivered by a centrifugal fan is directly proportional to its speed, i.e., if the speed be doubled the volume of air will be doubled.

The air pressure or static water gauge set up by a fan is proportional to the square of the speed, i.e., if the speed be doubled the air pressure will be increased four times.

The power absorbed by a fan is proportional to the cube of the speed, i.e., if the speed be doubled the power will be increased eight times.

The weight of air may be noted as being 0.0763 lb. per cubic foot when at 60 degrees F. with a pressure of 30 inches of mercury and relative humidity of 70 per cent.

A pressure of 30 inches of mercury is approximately 14.7 lb. per square inch, and relative humidity may be looked upon as the ratio between the amount of moisture in the air and the amount of moisture the air could contain when saturated at the same temperature. This definition gives a reasonable idea of relative humidity, the strict definition of which involves the conception of partial pressures.

The term "saturated" used in the above means that the air is carrying the maximum amount of water it can hold as vapour at the temperature specified, and it should be noted that a drop in temperature will cause some of the water vapour to con-

dense and settle out in droplets. The temperature below which condensation commences is called the "dew point."

CHAPTER V.

GRAIN DRYERS

For the bulk storage of grain for any lengthy period to be practicable, without any deterioration in quality, the moisture content should not be greater than 14 per cent. Grain with a moisture content of 16 per cent. may be stored in bulk provided it is "turned over" at intervals, or it may be stored in bags. If open bags are used, grain having a moisture content as high as 18 per cent. may be stored therein with reasonable safety.

From many points of view, grain lends itself admirably to bulk handling and storage, and it is worth while going to some trouble to eliminate such factors as may interfere with the effectiveness of bulk storage. Moisture content is one such factor and, therefore, the drying of grain to keep the moisture content within the limits prescribed above is commonly practised. It should be noted, however, that in an industry like the flour milling industry, drying is practised as part of the preliminary preparation of the seed for flour production, which factor introduces a number of restrictive conditions which are absent from the drying of grain for animal feed purposes. In compound mills, therefore, the drying of grain may be looked upon almost completely as a measure to improve the keeping qualities and will, of course, be influenced by the length of time it is anticipated the grain will lie in store undisturbed. It is true, however, that very wet cereals do not lend themselves as effectively to grinding as do dry cereals and under certain conditions, drying might be used as a preparation for grinding.

In provender mills, on the other hand, where cereal flakes are manufactured, it is often found necessary to dampen the grain prior to flaking, followed by the drying of the flakes. However, it is not intended to discuss process drying here.

Compound mills, almost without exception, do not contain grain dryers, although some few mills may have drying plants adjacent to them. Before discussing the actual dryers, it may be helpful to consider the broad principles of drying.

Wet grain spread out in a layer in a reasonably dry atmosphere will lose some of its moisture content naturally to the surrounding air, but for most industrial needs, this process is far too slow, and for commercial drying the application of heat by one means or another is an essential part of the drying process. The heating of the grain, however, whilst it speeds up the diffusion of moisture from the centre of the grain to the

grain surface and evaporates the moisture at the surface, requires for its most effective utilization the continual removal of the moisture-laden air from the vicinity of the grain. Essentially then, heat and ventilation are inherent requirements to commercial grain drying.

Drying may be split into two phases, in the first of which the whole of the surface of the grain is wet and in which the drying rate remains constant under uniform drying conditions, and in the second of which the surface of the grain is no longer wholly wet and in which the drying rate continues to fall. The first phase is called the " constant rate " period, and the second phase the " falling rate " period.

If the material being dried was completely non-absorbent and, therefore, carried no moisture other than that on its surface, the factors controlling the drying rate would be :

(1) The intensity of the drying heat (temperature).

(2) The humidity of the surrounding air.

(3) The rate of change of air or velocity of air flow.

In this case, the air velocity is a critical factor, with high air velocities resulting in high drying rates. With grain, however, the principal part of the moisture content will be found in the interior of the seed, and in this case, the drying rate will be controlled by the rate of diffusion of the moisture from the interior to the surface of the grain. Should the drying of surface moisture proceed at a much higher rate than the diffusion of moisture to the surface, the nature of the surface layer will be modified by shrinkage, as a result of which, it will offer increased resistance to the escape of the interior moisture and thus slow down the overall drying rate. The advantages to be gained from high air velocities in this case are not so marked as in the removal of surface moisture, but good ventilation remains a primary necessity of satisfactory drying.

It may be noted that air is not a particularly good vehicle for heat transfer because of its low specific heat (0.238) and its low weight per cubic foot, remembering that heat content per unit volume at any given temperature is determined by specific heat and weight of the substance. Air also is such a poor conductor of heat that it is the principal insulating agent in heat insulating materials for steam pipes and heating vessels.

The advantages of using hot air in dryers is explained rather by the enhanced moisture absorbing properties as compared with cold air than by its heating effect upon the grain. Air at 110 degrees F. can hold about seven times as much water vapour as air at 50 degrees F.

The application of heat by contact with hot surfaces probably finds its simplest expressions in the use of directly fired floor kilns, in which the heap of grain to be dried is loaded on to the

kiln floor under which is located a slow furnace or furnace flues. The removal of the surface moisture in such a kiln approximates a boiling process, but artificial convection of the grain must be achieved by periodic turning over to present new wet surfaces to the hot floor. Under proper control, the product of such a kiln can be quite satisfactory but the process is slow, uncertain, and can yield a high degree of variation throughout the mass of grain if the attendance is at all lax or unskilled. Other kilns allow the flue gases from the furnace to penetrate the mass of grain being dried and, in spite of the obvious dangers of contamination and local scorching, considerable quantities of grain have been dried by this method. It might be added here that bleaching of grain has been practised by burning sulphur on the furnace fire of a kiln in which the furnace gases come into contact with the grain.

Modern grain dryers found on mill premises almost invariably use indirect heating through hot water radiators and/or a stream of air which has been heated by passing over a nest of steam tubes. It should be realized that the mill premises referred to above are almost always flour mills and, as may be expected, the needs of the flour milling process have largely influenced the design of these dryers and for compound milling grain, the designs may appear to be unnecessarily elaborate. In the drying of grain for flour milling purposes, the maximum drying temperature should not exceed 115 degrees F. for wet grains, whereas for animal feeding purposes, drying temperatures up to 180 degrees F. may be contemplated. Generally speaking, the higher the initial moisture content of the grain the lower should be the drying temperature.

Grain received into the compound mill, if it has required drying at all, will normally have been dried prior to its receipt at the mill and, for this purpose, most grain growing areas contain one or more drying centres. To those centres farmers will send wet grain to be dried and the drying machines met with at country silos often display considerable differences in design from the flour mill dryer. Furnace flue gases are often used in these modern installations to heat up steel trays over which the grain is scraped. The furnaces may be oil or gas fired as an alternative to the older coke or anthracite firing. The most popular method of grain drying is to cause the grain to flow in comparatively thin streams between specially shaped hot water pipes in such a manner that all individual seeds are at some time in close proximity to the pipes and to follow this preheating by passing regulated currents of hot air through banks of grain not greater than six inches thick.

After heating the grain in the drying process, it becomes necessary to cool it, and this is done in the same apparatus by the action of cold air currents circulated in a similar manner to the hot air.

Fig. 89 shows a vertical cross section of a dryer manufactured by Messrs. Henry Simon Ltd., which can also be used as a conditioner. The grain to be dried enters the dryer through the feed bucket whose action is linked with that of the discharge gate at the bottom of the column and is so arranged that an increase in the rate of discharge is compensated by an increase in the rate of feed, thus maintaining a full column of grain. The grain is first heated by passing over and between a bank of water heated pipes forming a radiator.

Following the preliminary heating, the grain passes over a further five banks of water heated radiators between each bank of which is located a row of air ducts. Counting from the top of the dryer shown in the diagram, the 1st, 3rd and 5th rows of air ducts act as air inlets, whilst the 2nd and 4th rows act as air exhausts. The air entering the supply ducts is at atmospheric temperature and is heated in its passage over the radiators so that all the heat needed for drying is supplied by the hot water radiators.

After leaving the drying section the grain flows through the cooling section where it is subjected to currents of cold air

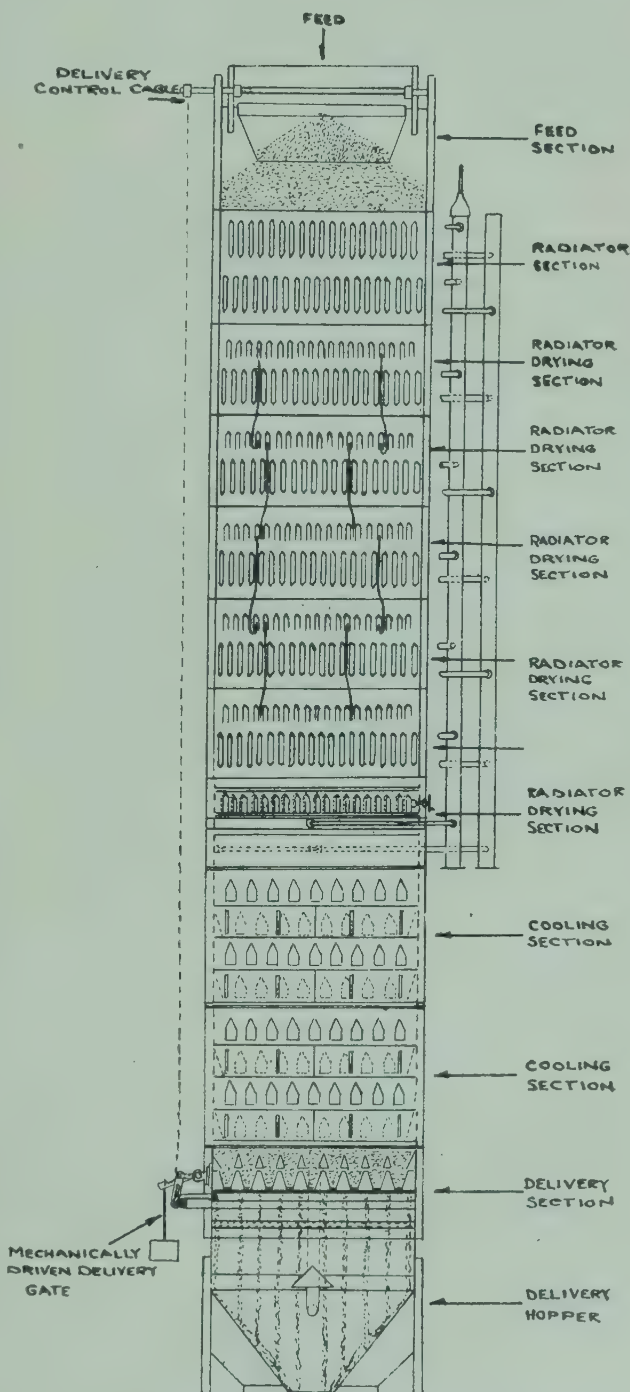


Fig. 89 Vertical Cross Section Conditioner Dryer

before being discharged from the delivery gate. For specific purposes the arrangement of the sections may be altered or the number of sections may be increased or reduced.

The radiators, which are of cast iron, are not fixed rigidly in place but rest on supports to allow the necessary freedom for expansion and contraction. Fig. 90 shows the arrangement of radiators and air ducts. The hot water used in the radiators may obtain its heat from a small furnace, or if steam is available,

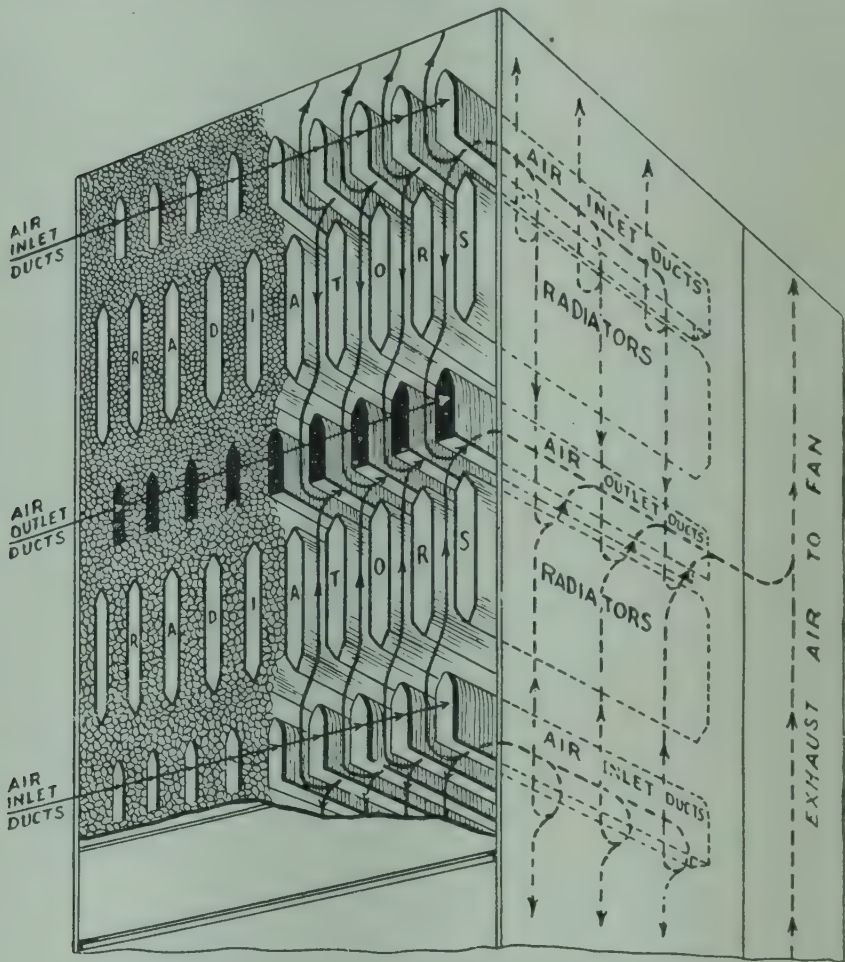


Fig. 90 **Arrangement of Radiators and Air Ducts**

this may be used to heat the water through the medium of a heat exchanger or calorifier. The calorifier consists of a cylinder containing a steam coil surrounded by the water to be heated. Convection currents set up in the heating of the water will normally cause the water to circulate through the system, but a higher rate of heat transfer is obtained from forced circulation by use of a water circulating pump. It will be understood that at no time are the water and steam in direct contact with each other and that the heating water leaving the radiators is returned to the calorifier for reheating and so back to the radiators.

The valve, supplying steam to the coil in the calorifier, is usually operated thermostatically. The opening of the valve is determined by the temperature at which the hot water leaves the calorifier. Should the water temperature tend to rise higher than is required, the excess of heat intensity transmitted to a heat sensitive mechanism reduces the valve opening, and alternatively, if the temperature drops, the thermostatic mechanism opens the steam valve to supply more heat.

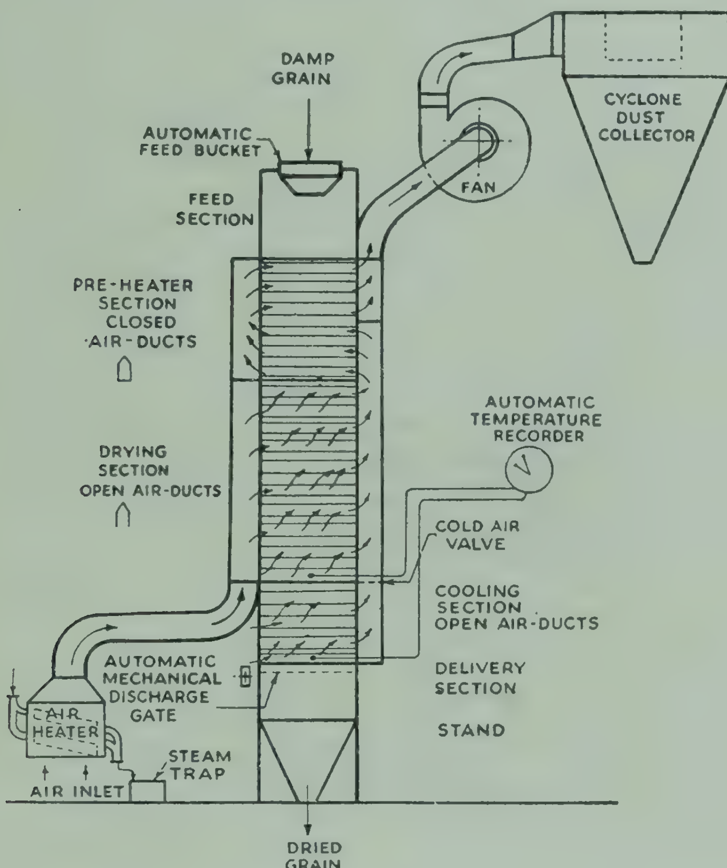


Fig. 91 Hot Air Dryer Arrangement

The cooling air and the drying air are both induced to flow through the grain by the action of a single fan located in the exhaust trunk line and the air leaving the fan is cleaned in a cyclone separator before discharging to the atmosphere.

To use the dryer, assuming that the radiator circuit has been filled with water and that there is a steam supply to the calorifier, dry grain is fed to the machine, in at least sufficient quantity to fill the cooling section and the remainder of the column is filled with the grain to be dried. If dry grain is not available, damp grain will have to be used, but the first half column of grain to be discharged from the dryer should be returned either to the top of the column or to the wet grain store for re-drying.

Until the dryer is completely filled with grain, the air fan

must not be run, otherwise grain may be sucked into the exhaust trunk. The movement of the discharge gate is synchronized with that of the feed gate to give the required rate of flow by adjusting the length of the control cable. The grain is raised to the maximum allowable temperature in the first heating section and is afterwards treated to such ventilation as is required as it passes down the column. To control the ventilation, a number of air dampers are provided at various levels as well as a master damper in the exhaust trunk line. The master

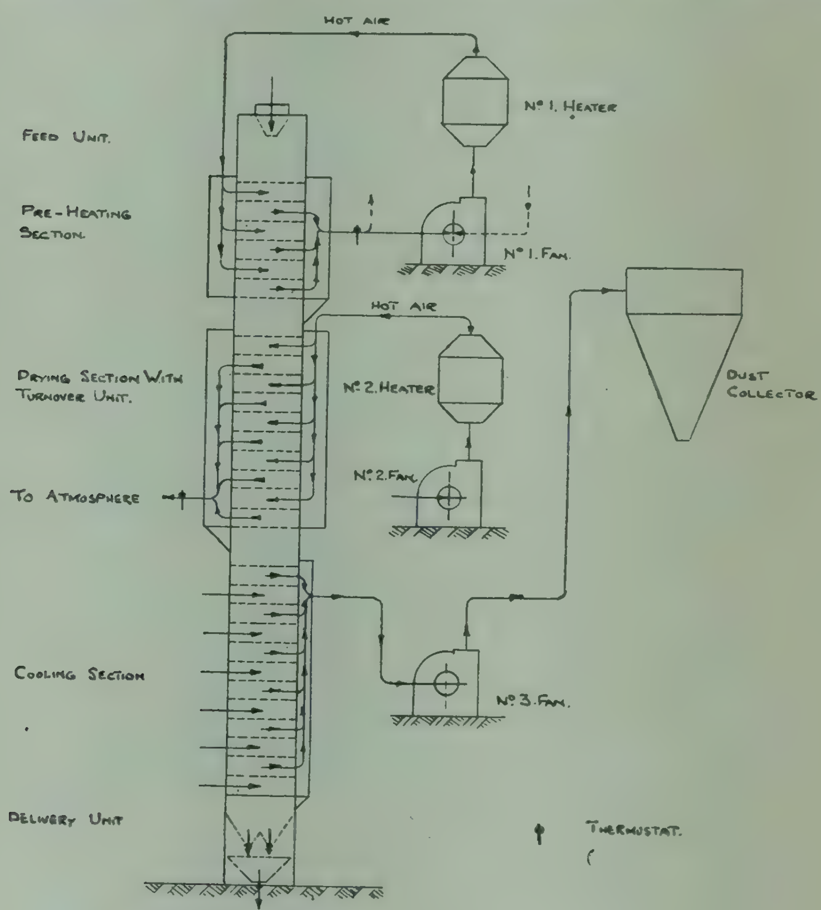


Fig. 92 **Universal Conditioner Dryer**

damper controls the overall ventilation whilst the dryer dampers determine the distribution of the air between the sections.

For efficient operation, no more air should be used than is necessary for the degree of drying required whilst the grain temperature should be kept as high as is consistent with the safe drying. The effect of the time factor upon the drying process should not be overlooked and an increased length of time in the dryer will increase the amount of moisture it is possible to remove from the grain. This dryer is designed to reduce the moisture percentage figure from about 20 to 14, but if required, a greater drop than this can be obtained under suitable conditions. The normal complete process time is 110 minutes.

A check on the adequacy or otherwise of the air flowing through the grains may be obtained by measuring the grain temperature at the bottom of the drying section. If this temperature is much below that of the grain leaving the heating section, too much air is being used. If the temperature is much higher than the working temperature, too little air is being used.

A grain dryer in which the drying process is completely effected by the use of hot air currents is shown diagramatically in Fig. 91. The comparative simplicity of its construction makes it a cheaper apparatus than the water heated radiator dryer, and the higher cost of operation is not such a serious criticism where the dryer is only used at special times, as for instance after the harvesting of a grain crop, and is idle for best part of the year. The hot air dryer is particularly suitable for the drying

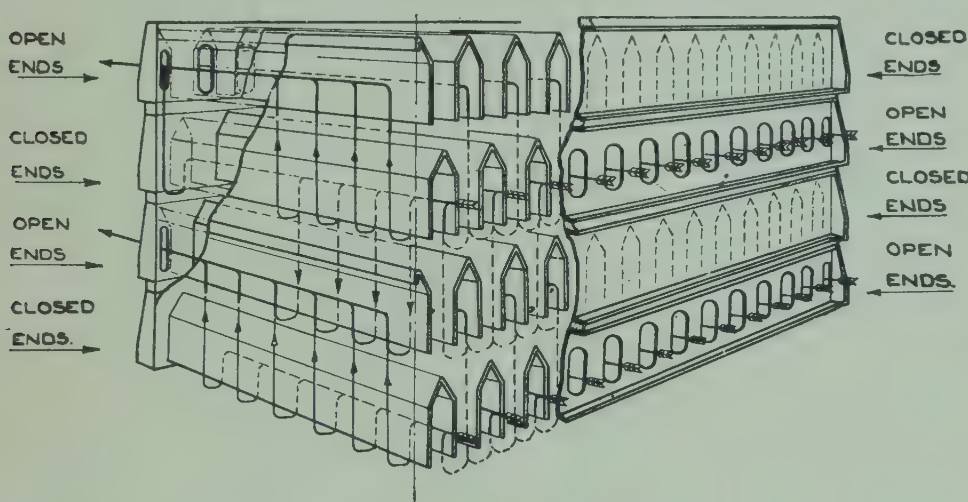


Fig. 93 **Detail of Air Ducts for Universal Dryer**

of grain carrying a large amount of surface water, that is to say where there is a fairly long " constant rate " period, and lends itself to the preparation of grain for storage. In Fig. 91, which illustrates a Simon machine, an air heater is shown in the common suction air inlet duct although there are variants of this.

The hot air upon entering the column passes through open type ducts and so into contact with the grain surfaces where it absorbs moisture from the grain. The damp air then passes through a double bank of closed ducts and out to the exhaust fan. In the closed ducts, the heat contained in the damp air is utilized to preheat the grain before the grain enters the ventilating section. The feed and discharge gates are again interlocked and the diagram indicates the fitting of an automatic temperature recorder. The cooling section is similar to the drying sections but cold air is drawn through the grain.

The inside of the air trunk is lined with insulating material to minimize heat loss, and in fact all hot surfaces not being

used as heat transfer surfaces should be lagged with heat insulating material in the interest of economy.

Whilst these machines are of very simple construction, maintenance notes issued by the makers include instructions to examine the interior of fan trunks and ducts for lodged dirt or foreign matter and the inside of the column for sticks and straw whose accumulation may interfere with the free flow of grain down the column and from the discharge gate. To ensure free working of the discharge gate, it is advised that a clearance greater than the size of the grain being dried be left between the bottom of the hopper and the top of the gate; 3/16 inch minimum in the case of wheat.

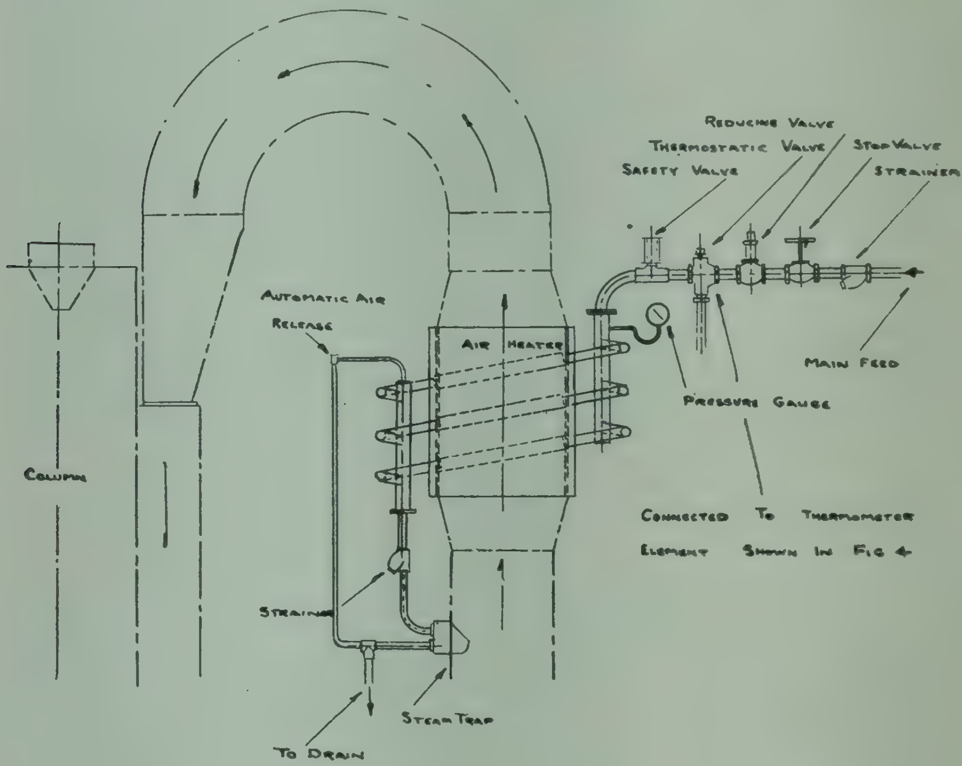


Fig. 94 **Air Heating Arrangement for Universal Dryer.**

Air ducts on the exhaust side of the dryer, which are in contact with hot, humid air, should be examined for internal corrosion and as an anti-corrosion measure it is recommended that when the dryer is empty the hot air should continue to be circulated for thirty minutes to dry out the inside of the apparatus.

The Universal Conditioner Dryer of Messrs. Thomas Robinson & Son Ltd. is another hot air machines whose general construction is indicated in diagram 92 which indicates its use as a dryer. It will be seen that there are three distinct air flows for preheating, drying and cooling respectively. The feeding, discharge and grain flow of this dryer are similar to most

column type dryers, differences between various types being found in the heating medium and the sequence and distribution of heating and ventilating. In the column illustrated, the grain is given its preliminary heat treatment by direct contact with hot air fed through ducting of the type illustrated in Fig. 93, whilst removal of moisture in this section is retarded by recirculation of the same air although provision is made for the admission of fresh air to control the humidity.

Between the preheating section and the drying section is a blank length of about 18 inches which serves as a seal between the two. The air in the drying section which is blown through the grain is exhausted to atmosphere as this will carry with it the bulk of the removed moisture. The cooling section, which follows a further sealing length, has the cooling air drawn through it by the third fan. The cooling air is exhausted from the fan through a cyclone separator to remove entrained light grain, husk, straw, etc., before discharge to atmosphere. Control of temperatures is effected by the thermostats located as shown in the diagram. The thermostats control the steam supply to the air heaters through a valve which is indicated in Fig. 94.

CHAPTER VI.

GRAIN STORAGE

The history of grain storage is largely the history of silo development from the early holes in the ground to the modern port grain store with its nests of deep bins and its highly mechanized handling of bulk grain. The use of silos is peculiarly associated with the storage of cereal grains and in present day terms usually refers to a nest of deep bins adjacent to one another and housed in one building. In America, the building, the bins housed therein and the handling plant is called a "grain elevator," and the word "silo" is often used in our own country as synonymous with the American "grain elevator."

A grain silo located at a port is referred to as a port silo or, in America, as a "terminal elevator," whilst the development of home-grown cereal drying in England during the late war led to the erection of a number of so-called "country silos" in inland localities, incorporating drying plants. In contrast with this use of "silo" to describe a complete bulk storage installation is the practice of referring to one deep bin as a silo, as occurs for example in a Home Office report upon a silo explosion which occurred in a compound mill. How far the study of large scale installations for the storage of bulk grain is pertinent to the study of compound milling technology is a debatable question, in view of the comparatively minor place

played by original grains in the compound milling industry. The provender miller, however, who is preoccupied with the manufacture of straight cereal products may properly find advantage in the silo storage of grain.

A brief survey of grain silo construction and operation should enable the compound milling student to determine in broad outline how far silo storage as applied to grain is suitable for compound milling materials, and what modifications are likely to be required to make it more suitable.

Viewed from the standpoint of the grain trade, a silo consists of a nest of deep bins which may contain as few as, say, four bins, or, in a large silo, may contain thirty or forty, whilst the Liverpool silo of the Liverpool Grain Storage and Transit Co. Ltd. contains two blocks of 141 bins each and of a depth of 116 feet. J. F. Lockwood, in his book " Flour Milling," makes the point that except on good natural foundations, 60 feet may be considered to be the economical height of a silo, whilst the diameter may vary from 6 feet to 30 feet with 20 feet as an economical limit.

The materials from which grain silo bins may be constructed are various (reference should be made to page 133 of the first year text book), but the modern trend is to use reinforced concrete which has many advantages, amongst which may be numbered :

1. May be built rapidly.
2. Low maintenance costs.
3. Fireproof.
4. Vermin proof.
5. Unaffected by climatic conditions.
6. Does not require a further building to house the bins.
7. Lends itself to pleasing appearances.

The operation of a silo involves the reception of the grain, the feeding of the bins, turning over from one bin to another to prevent or arrest heating of the grain, drying and discharge to mill or transport vehicles. Silos forming part of a mill premises will also have facilities for dampening the grain in a conditioning process, for which purpose a number of small bins are provided. The intake of grain usually involves a weighing and preliminary cleaning process. The first as a commercial necessity and the second to ensure free running of the plant and the best keeping condition for the grain.

Grain which shows signs of becoming warm due to its biological activity, a fact which is usually indicated by electrical bin thermometers in modern systems, has need to be aerated in order to dissipate the heat generated and to arrest further heating. This aeration is achieved by passing the grain out of the bin which contains it and through suitable handling plant

into another bin. The handling machinery used in the turning over of the grain may be the same as that used for intake purposes but, generally speaking, it is much more satisfactory if separate elevators and conveyors are provided for "turning over."

Apart from biological changes which occur, the rise in temperature due to "heating up" increases insect activity in the grain. Generally speaking, insect pests in stored grain are not active below 50 degs. F., and with infested cargoes, turning over keeps pest depredations at a minimum, particularly in cold weather.

In flour mill silos, it is rare that anything more than about 25 per cent. of the grain handled needs drying, but provender manufacturers often receive grain which is damaged or otherwise unsuitable for flour manufacture and at times grain may be received which has been damaged by water or has been lost to the flour mill due to poor growing and wet harvesting; all this grain will need to be dried either at the growing centre or in the provender mill silo, if it is within reasonable distance of the growing centre.

There is, however, a considerable amount of literature available upon the subject of grain silos which is not the case for silos used for compound milling materials. The difference between silo storage of grain and silo storage of compound raw materials does not simply resolve itself into a question of providing steeper hopper bottoms for compound mill silos. In passing, it may be noted that the word silo in compound milling parlance almost always refers to a single deep bin.

The handling and storage of grain is a very different proposition from the handling and storage of most compound raw materials. Grain, by virtue of its particle size and shape and non sticky character, lends itself admirably to bulk handling and storage without any pretreatment other than simple cleaning and, in a few cases, drying. Many compound materials on the other hand, as received, do not lend themselves even to bulk handling, let alone bin storage. Materials for instance like slab oil cake or locust beans present special difficulties. Slab oil cake presents the paramount difficulty for, obviously, this must be broken before it can possibly be stored in a bin. The kibbling of slab oil cake whilst not in itself a difficult task, does however present the problem of performing the kibbling at the discharge point of the transport vehicle and at a rate that will not cause the vehicle greater delay than would be required in the unloading of, say, bagged maize into a bulk hopper.

If the slab cake is received into the mill in slab form, bagged or otherwise, and afterwards kibbled to allow of bin storage, an economic loss is occasioned by the double handling. Locust beans may be mechanically handled, but if unbroken, the risk

of arching in the silo bin is very real. In fact, one of the big problems associated with deep bin storage is the difficulty of inducing the stored material to flow from the bin. Even the risk of silo explosions would be very slight if materials never "held up" in the bin.

Materials like slab cake, locust beans, and expeller curves are in the normal condition when received in large pieces, but other materials which, when leaving their point of origin are in meal form, quite frequently become consolidated into lumps in transit or in parcel store. When bags of such material are received at the mill, the contents of the bags often need severe treatment to break up the lumps. A good example of a material prone to this consolidation is rice meal and, in fact, rice meal although normally in a finely divided state, is occasionally put through a kibbling machine to break up the lumps. It will be clear from this that adequate kibbling capacity is a primary essential of a compound mill silo house, although some millers buy all their materials in a kibbled form for which, of course, they pay higher prices.

No really adequate automatic weighing of all incoming bulk materials is practicable without a considerable range of weighing machines to cover extremes of densities and flow characteristics unless, of course, the weigh pan of a machine be constructed to carry a weighment of the lightest material and continual readjustment be made of the compensating balance, and even then it is doubtful if one feed mechanism could be designed to handle satisfactorily the full range of compound milling materials. Preliminary cleaning of the type so much a feature of the grain silo presents new problems when associated with compound mills, and probably the only cleaning that can be done at the intake point or prior to grinder is that represented by the grizzly and magnetic separator, and even these are subject to restrictions.

Expeller curves, locust beans and slab cake, even when reduced to a size suitable for bulk storage, would still present in particle size a big difference from, say, barley or extracted meal. Clearly, under such conditions, talk of sand screens for instance becomes facetious whilst machines like scalperators, millerators, receiving separators, rubble separators become of very questionable value. Unless, of course, the miller is sufficiently prodigal to install a separate intake point for each of the various categories of raw materials and restrict their use to those materials. It would be very interesting to develop this theme further, but as the present purpose is to indicate the complications that arise in bulk storage of raw materials and to trace the effect of those complications upon the nature of the plant and equipment necessary to a compound mill bulk raw material store, sufficient has been said about preliminary clean-

ing to suggest that, apart from the robust, coarse bar screen and the magnetic separator and as a refinement perhaps a rubble separator kept exclusively for grain, cleaning machinery is not likely to be conspicuous.

Having prepared the raw materials for bin storage the two main problems now to be faced are, first, the choice between a minimum number of large bins and a greater number of small bins. Large bins, whilst cheaper in first cost, must be kept full if proper advantage is to be taken of the storage volume. Forty tons of a material that is needed only in small quantities occupying a 120 ton bin is clearly wasteful, so that some small bins for such materials are necessary. In any case, the minimum number of bins required for complete storage of a full range of raw materials is not likely to be less than thirty, allowing only one bin per material and some materials will need several bins, thus a five or six bin silo as met with in grain storage is inconceivable in a compound mill without a great deal of bag storage capacity.

The second problem, that of inducing the stored materials to flow from the bins containing them, is one which is always present with such a diverse range of materials. What answers for one material may not suit another. Many are the solutions offered to the bin discharge problem. One of the greatest difficulties and dangers is the arching of material half way up a bin and every precaution must be taken to avoid this. Steel, with its comparative low coefficient of friction, makes it a favoured material for compound mill bins, but the disadvantages of sweating and the facility with which heat may travel through steel plate still makes timber a serious competitor for bin construction.

A variety of designs of bin hoppers and dischargers has been produced from time to time, all with the object of eliminating the difficulties associated with the discharge of sluggish materials. A number of other devices as, for example, cross beams staggered down the depth of the bin, have been used to reduce the consolidation of material in the bin.

CHAPTER VII.
SIZE SEPARATION

Size separation is the principle underlying a great many of the machines used for the cleaning and grading of compound materials. Sieving, or screening, are popular names given to the process and clearly indicate the use of screens or sieves. There are, however, a number of other machines which make use of a particle size difference for the separation of two materials and which are neither sieves nor screens as, for

instance, the indented cylinder and the disc separators so common in the flour milling industry. For compound milling materials, however, it is safe to say that all cleaning of materials which depends upon the particle size of the materials is effected by screens of one sort or another. The separation by size is performed by passing the material to be cleaned or graded over or through a perforated surface which may be flat or curved and may be composed of bars separated from each other, perforated metal woven wire which in the finer sizes is referred to as wire cloth, or silk or cotton fabric.

Bar screens, as the name suggests, are formed of bars fastened together in a frame in such a manner that a predetermined distance between them is maintained. The bars may be of rectangular cross section or, for very coarse work, of

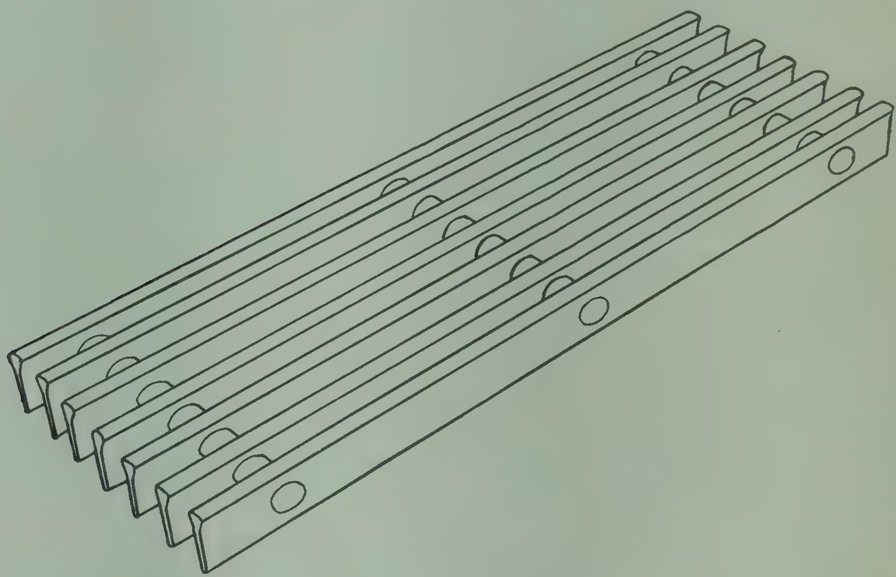


Fig. 95 **Wedge Bar Screen**

circular cross section, but the most efficient bar is that having a wedge shaped cross section (Fig. 95).

It will be clear that the use of wedge bars minimizes the blocking or blinding of the screen by material which is close on the limiting size. Bars having parallel faces may cause a tapering effect in the hole due to variations in the rolled thickness of the bars, skin projections on the bar surface or, as is more likely, due to inaccuracy in fitting. If such should be the case, the result might be as shown exaggeratedly in Fig. 96A. With wedge bars, on the other hand, any of the imperfections mentioned are more than allowed for by the progressively increasing space between the bars over their depth. If, however, the bars are part of a semi-circular or curved screen, rectangular bars are completely effective by virtue of their radial location (Fig. 96B).

A typical assembly of bars is shown in Fig. 60 in the first year text book, where they are used as a rough intake screen.

Perforated metal presents a screening material of almost limitless variation and it would be most illuminating for a student to obtain sight of a catalogue of any large scale manufacturer of perforated plates. All shapes and sizes of apertures of different pitches and in different formations are punched in many thicknesses of plates. Most of the punched holes have parallel sides throughout the thickness of the plate but others are tapered or countersunk.

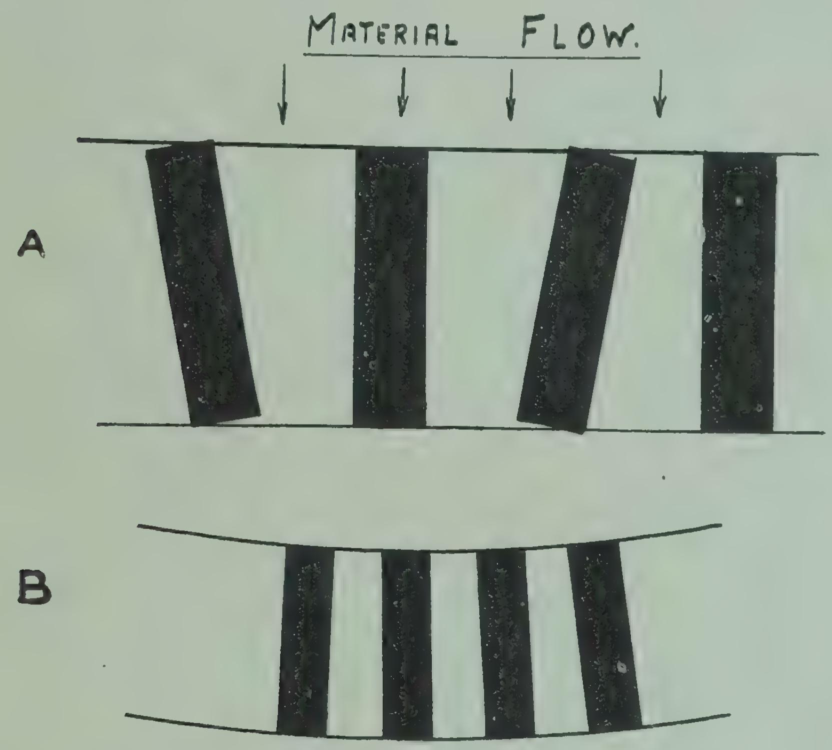


Fig. 96 (a) and 96 (b)

Probably the most common shapes of apertures are round and rectangular. The most common rectangular holed or slotted plates have perforations which are not strictly rectangular, for the ends of the slots are semi-circular. Perhaps the most important single fact to remember about perforated plates is that, even ignoring all questions of thickness, the screen is not completely specified by the size of the holes punched in it; for example, Fig. 97 shows a series 3.5 mm. perforated screens, and whilst the size of the " throughs " will be the same in all cases, the performances of machines into which they were fitted would vary tremendously over the range of pitches of the perforations.

A not dissimilar characteristic is found in the case of woven wire screens where the controlling factor is the thickness of the wire used in the manufacture of the screening cloth. Strangely enough, whilst perforated screens are loosely identified by the size of the perforations, woven wire screens are almost invariably sized by the number of perforations per lineal inch. The use of perforated plates which have been specified by perforation

size can result in a screen throughput other than that expected (ignoring at this point all question of screen life), whereas the use of wire cloth specified by mesh only can yield a grade of product completely unsuitable for the intended purpose. This will be readily appreciated by considering the following example. Suppose a wire having a diameter of 1/10th inch is used to weave a cloth having five meshes per lineal inch, part of the inch would be taken up by five wires each having a thickness of

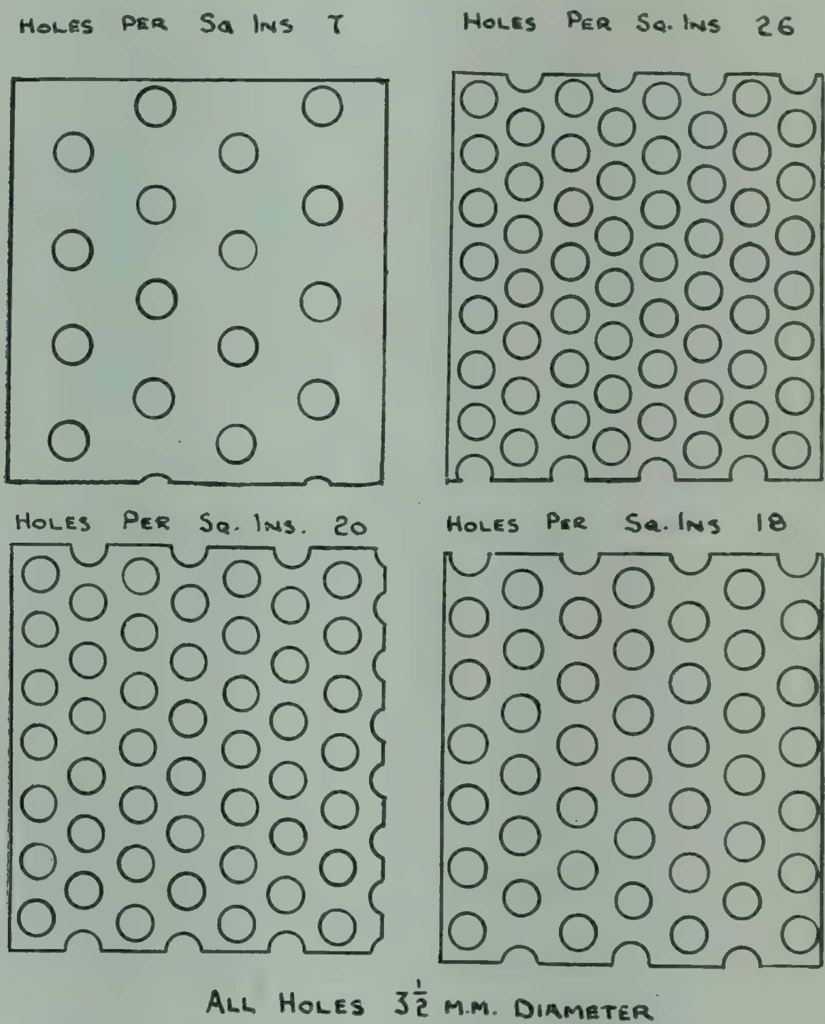


Fig. 97

1/10th inch which totals ½ inch, leaving ½ inch space shared amongst five holes, so that each hole would be 1/10th inch wide.

Suppose now that another sample of 5 mesh cloth is made from wire 1/20th inch in diameter, there would still be five wires in each inch of cloth, but this time they would only occupy 5 × 1/20th inch = ¼ inch, leaving ¾ inch to be allocated between the five spaces, so that each space would now be 3/20th of an inch wide, that is 50 per cent. wider than the holes in the

first cloth. Thus, a material screened by the second cloth strictly to size would be 50 per cent. larger in at least two directions than material screened by the first cloth, and yet they have both been screened through a so-called 5's mesh screen.

It should be clear from this that it is most necessary to specify the size of wire as well as the number of meshes per inch when a particular size of product is required. Actually, the British Standards Institution have drawn up a number of lists of standard screens for specific purposes, and whilst in the main the fineness of compound mill screening is largely subject to the miller's own ideas, in certain instances a specific size of particle must be adhered to as, for instance, with calf gruel. The fourth screening material, cotton fabric or silk cloth, is used in compound mills only for air cleaning purposes as in a bag filter following the cyclone in a pneumatic elevating system.

The screening medium used in any particular instance will depend upon a number of factors, the more important of which are: The actual sizes of the particles to be separated, the throughput per square foot of screen surface and the severity of the service.

Where, for instance, rough rubble separation is required with fairly heavy usage, bar screens might be a first choice, whereas, for sifting calf gruel, wire cloth might be an automatic choice. For use in grinding machinery, bar screens give a good life but are not as selective as perforated plate. After having made the first selection of the type of screen, a balance must now be decided upon between the life of the screen and the throughput required. With bar screens, narrower bars will give a greater clear area per square foot of screen; with perforated plate, a larger number of holes per square inch will give a greater clear area per square foot of screen; and with wire mesh for a given size of hole, a lighter wire will increase the number of holes per square inch. The use of a greater free or clear area as indicated by the above, however, will reduce the life of the screen.

Some of the characteristics of the actual screening surfaces have been considered and it is proposed to deal with some of the methods of using those surfaces. Fixed screens are the least effective of screening devices, although it should be borne in mind that the use of terms like effective and efficient in this connexion can be very misleading, and in describing a screen as efficient or inefficient account has to be taken of the question of suitability for a purpose. The use of the term efficiency seems to involve the statement of a number of qualifying conditions.

It is not unreasonable, however, to consider that that screen is most highly efficient that most effectively performs the duty for which it is used, and as most milling purposes involve the achievement of minimum cost in attaining given conditions, the

effect of cost must necessarily enter into all practical considerations of efficiency where a departure is made from the mere mechanical efficiency of work got out divided by work put in. From this point of view, an intake bar screen intended for the removal of large pieces of rubble, although stationary, can be considered an effective piece of apparatus.

For more selective separations using screen perforations falling within fairly narrow limits of size, the stationary screen compares unfavourably with a moving screen surface. A stationary screen is required to be set at a fairly large inclination in order that the material to be screened shall move over its surface, whereas with certain types of moving screen, the screen surface may be perfectly horizontal.

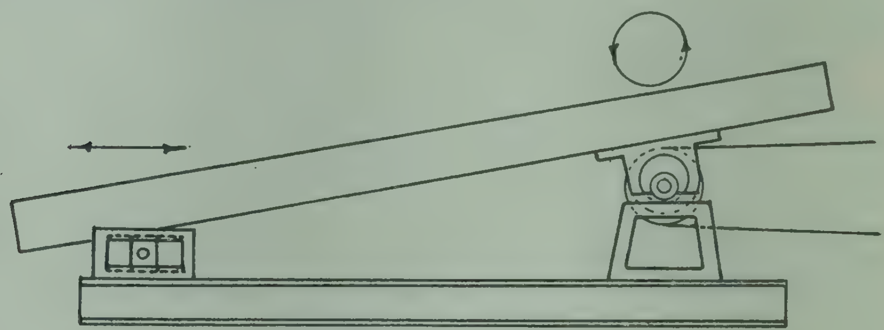


Fig. 98 The Simple Jogger

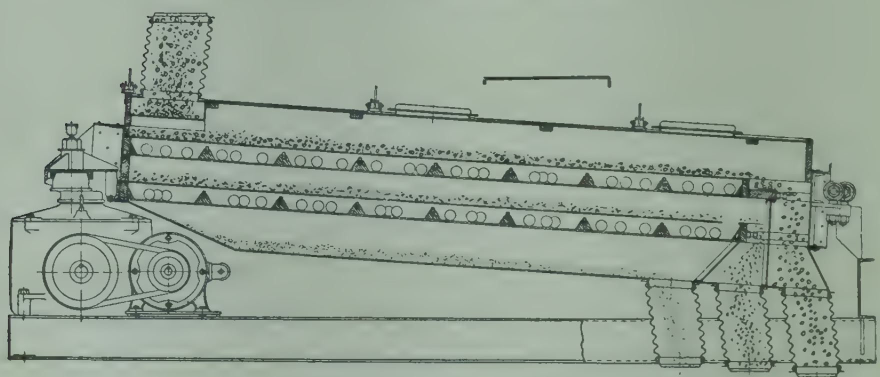


Fig. 99 The Locker Rotex

The disadvantage of having large angles of inclination is that a fair amount of those particles which are small enough to go through the perforations in the screen are carried down the incline by the larger particles and thus reduce the degree of separation achieved. The separation of materials from one another by virtue of the difference in volumes which the particles occupy produces in any bulk of material a stratification, even in the absence of any deliberate movement of the material, but with a suitable motion imparted to it a bulk of material will quickly settle into layers of the smallest particles at the bottom and the largest at the top in spite of differences in densities which may exist.

This separation by volume is a considerable asset to moving screens lying at fairly flat angles, in that when a good depth of material is to be maintained on the screen it feeds the smaller particles down through the bulk on to the screen surface and thus into proximity with the perforations.

The particular kind of movement imparted to a moving screen may be one of a fairly extensive range, but where the movement is not simple rotation or simple reciprocation, then it is one of the many combinations of these two. It should be noted, however, that some of the simple movements may occur in any one of a number of different planes. Examples of some representative movements may be found in:

(1) The simpler jogger (Fig. 98) in which one end of the screen box is rotating in a vertical plane whilst the other end is constrained to move horizontally. This movement conveys the material down the screen in a series of hops at the feed end to almost pure sliding at the tail end.

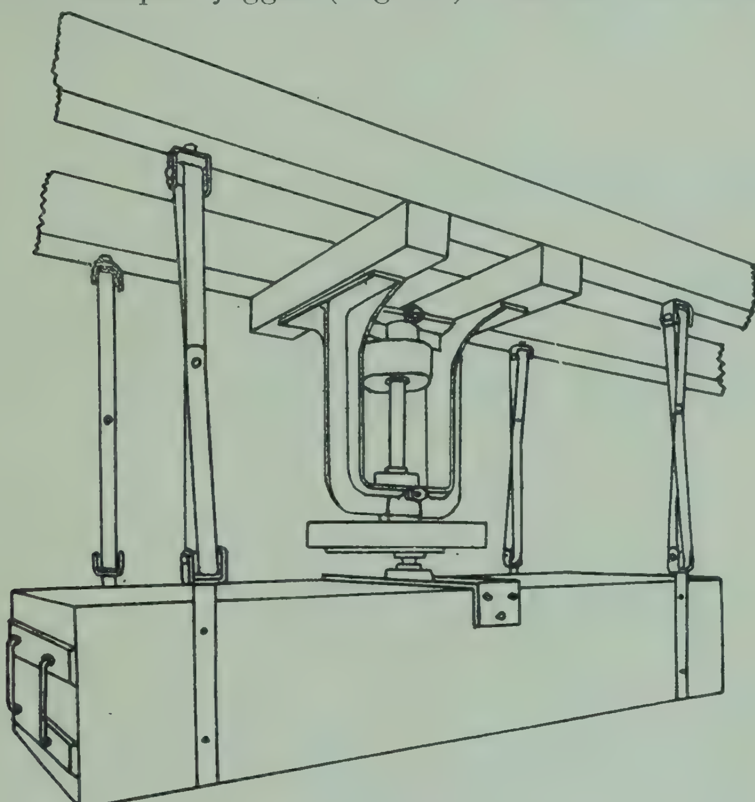


Fig. 100 **Rotary Screen**

(2) The screen driven by a "Juby" or similar self-balancing mechanism which imparts pure reciprocating motion.

(3) The screen that is given a rotary motion in a nearly horizontal plane at the feed end and is contrained to reciprocate at the tail end. The Locker Rotex (Fig. 99) is an example.

(4) The rotary screen, in which the whole screen moves with a circular motion (Fig. 100).

Some of these movements are designed to increase the capacity of the screen whilst others determine the kind of separation that is effected, e.g., pure reciprocating motion tends to separate materials by virtue of differences in their smallest dimensions, whilst rotary motion in a horizontal or nearly horizontal plane separates materials by virtue of their greater dimension. That this should be so is explained in the following manner: Long, slender particles lying on a reciprocating surface tend to lie with the long axis in the direction of motion of the surface. When the screen is moving in the forward direction, the particle on its surface acquires a momentum, and when the screen stops upon reaching the end of its forward stroke the momentum of the particle tends to make the particle continue to move in the direction in which the screen had been

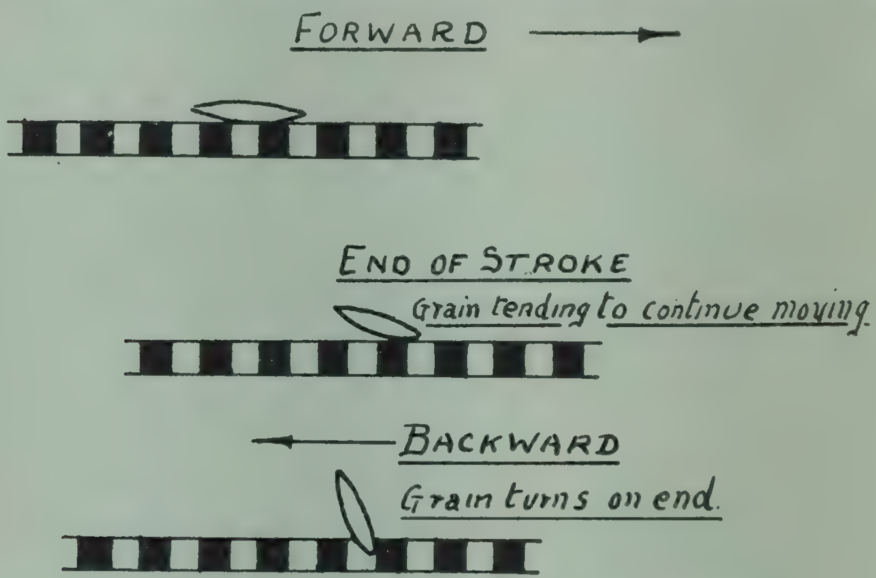


Fig. 101 Separating Action of Reciprocating Movement

moving. This movement of the particle is arrested by the friction between it and the screen surface and the suddenness of the braking action causes the tail end of the particle to lift so that it tends to stand on end. This tendency is exaggerated by the sudden movement of the screen in the opposite direction and the particle, end on to the screen, can now pass through a perforation which would have rejected it had the particle presented its longer axis to it (Fig. 101).

If, however, the screen is moving with a circular motion there is no sudden arresting of particle movement and the particle, therefore, continues to lie flat on the screen and thus it always presents its longer axis to the screen perforations. A type of moving screen which, although not very efficient, is still widely used is the reel or trommel. This machine occupies a disproportionate amount of space for the work it does but gives little trouble in maintenance. Its inefficiency is explained

by the facts : (1) that a very small proportion of the screen surface is in use at any instant and (2) that that part of the surface which is in use is in such a position that the perforations are not presented squarely to the material, so that in the direction of the gravitational pull the plan diameter of the perforations is less than their actual diameter, and the speed of rotation of the perforated cylinder is not sufficiently great to impart to the particles a centrifugal force equal in magnitude to the pull of gravity. Fig. 102 illustrates the operation of a reel.

A development of the reel is the centrifugal, in which revolving arms or beaters throw the material against the perforated internal surface of a cylinder similar to that used as a reel. The average speed of a centrifugal cylinder is about 20/30 r.p.m., whilst the beaters revolve at an average speed of 200 to 250 r.p.m.

Fig. 102

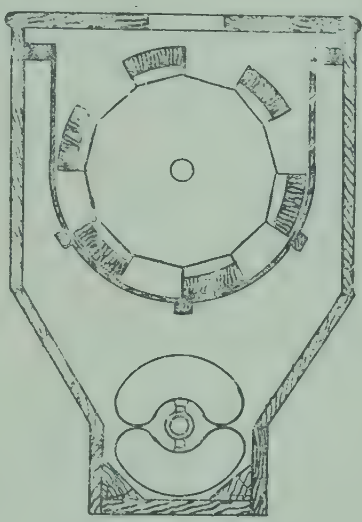


Fig. 103 Brush Sifter

The axis of a centrifugal is normally horizontal and the material is conveyed through the cylinder by the paddles formed by a slight twist in alternate fingers of the beaters. Due to the conveying action of the beaters, centrifugals may be fed at each end, delivering their overtails into two spouts located at the centre of the machine. The "cylinders" of both reels and centrifugals may be round or polygonal in cross section. Another machine in which the material is brought into positive contact with screening surface is the brush sifter which is probably best described as a perforated worm trough carrying a shaft to which are fastened brushes often in a spiral shape similar to a worm blade and which brush the material to be sifted against the perforated side of the trough. The "throughs" are collected by a worm conveyor underneath whilst the overtails may be returned to a grinder or other size reduction machine or may be directed to some other process (Fig. 103).

All the aforementioned machines may be fitted with perforated metal, wire cloth or silks, depending upon the purpose for which they are used.

A common failing of most screening media is a tendency to become "blind" by the filling of the screen apertures with size, or slightly oversize, material, and a number of devices have been used to prevent this "blinding." The screen illustrated in Fig. 99 employs a device which very successfully maintains a clean condition of the screen surface. At a short distance under the actual screening cloth is mounted a second very much coarser cloth. The second cloth is used to carry a number of rubber balls and the space between the cloths is divided up by a number of wedge shaped blocks. The motion of the screen causes the the rubber balls to bounce against the blocks, and from the blocks on to the underside of the working screen surface. The repeated impact of the balls constitutes a series of hammer blows

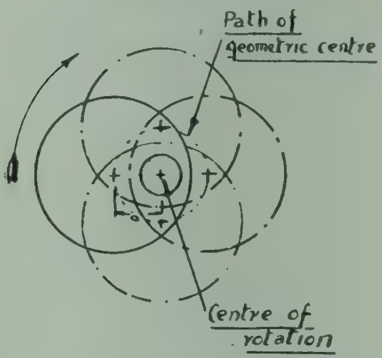


Fig. 104

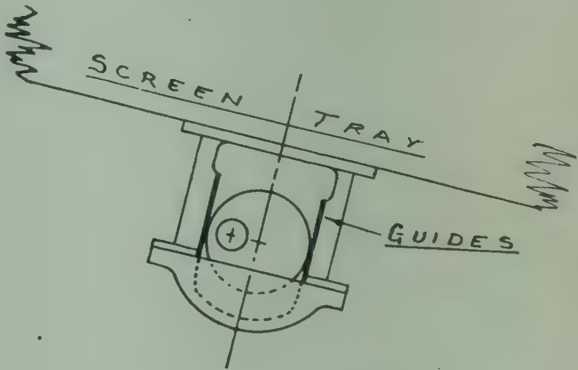


Fig. 105

which effectively retards the lodging of particles in the screen mesh. Reels are sometimes fitted with brushes which run against the perforated face during the non-working part of the revolution.

DRIVING OF SCREENING MACHINERY.

The eccentric is probably the most widely used mechanical device for imparting both rotary and reciprocating movement to screen surfaces, and students should understand the construction of a simple eccentric block and straps.

Firstly, the contour of the eccentric block is circular, and whilst this may seem to be an obvious fact, egg shaped eccentric blocks still proceed from students' pencils. The eccentricity of the block is due entirely to the fact that the block revolves around a point which is not the centre of the circle which forms the block's perimeter (Fig. 104). The distance (a) in Fig. 104, i.e., distance between the geometric centre of the block and the centre of rotation of the block is called the throw and the linear movement of any object operated by the block will be twice this distance (a). Thus, a reciprocating sieve driven through an

eccentric block having a throw of ½ inch would have a stroke of 1 inch. In order that the movement of the eccentric be transmitted to the screen it is necessary to house the block in a bearing which may be fastened either directly to the screen box or may be connected to the screen box through a connecting rod. If the eccentric bearing block is fastened directly to the screen box it will impart to the screen surface a rotary movement in the same plane as that in which the eccentric is revolving, but if the bearing be connected to the screen box through a connecting rod, reciprocating motion will be imparted to the screen. An eccentric block running between parallel guides mounted on the screen box will also impart a reciprocating movement to the screen (Fig. 105). Where the motion of the eccentric is con-

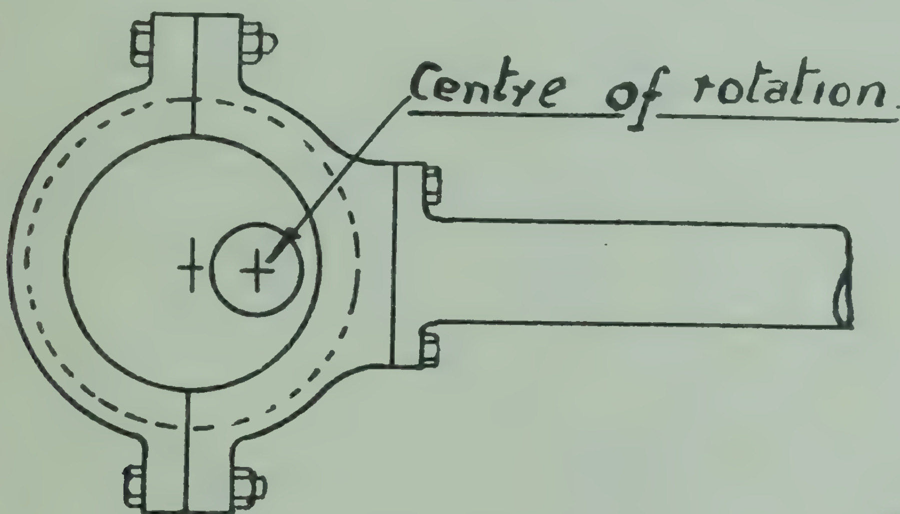


Fig. 106 **Eccentric Block and Straps**

veyed through a connecting rod, one end of the rod carries the bearing in which the eccentric revolves and the two halves of this bearing are known as the eccentric straps (Fig. 106).

Running at the speeds necessary for most efficient operation, the unbalanced action of an eccentric will set up vibrations which may become extremely unpleasant, if not actually dangerous, to the stability of the surrounding structure. The attempt to produce a balanced mechanism which imparted a reciprocating motion led to the development of the Juby drive (Fig. 107).

The Juby drive consists of two equal sized gear wheels running in mesh and fitted with equal weights, the wheels being assembled in an oil tight gear case and mounted on the moving frame of the screen. One gear wheel is driven through a pulley mounted on an extension of its spindle. Each gear wheel considered independently constitutes an unbalanced revolving mass which will set up reaction forces in a direction opposite to that in which the weight is moving. These reaction forces will tend

to move the member to which the gear is fastened in a direction opposite to that in which the weight is moving. With a single wheel and a freely suspended frame this would result in a rotary motion, but by arranging for a second unbalanced mass to induce contrary reaction forces at some parts of the cycle and complementary reaction forces at other parts, a practically pure reciprocating action is attained and this with a minimum of out of balance forces. In Fig. 108 are shown various positions of a screen tray moving under the influence of a Juby drive; positions (A) and (C) indicate the gear wheel weights acting together to produce a reaction force which is balanced by the moving of the screen tray in the opposite direction. In positions

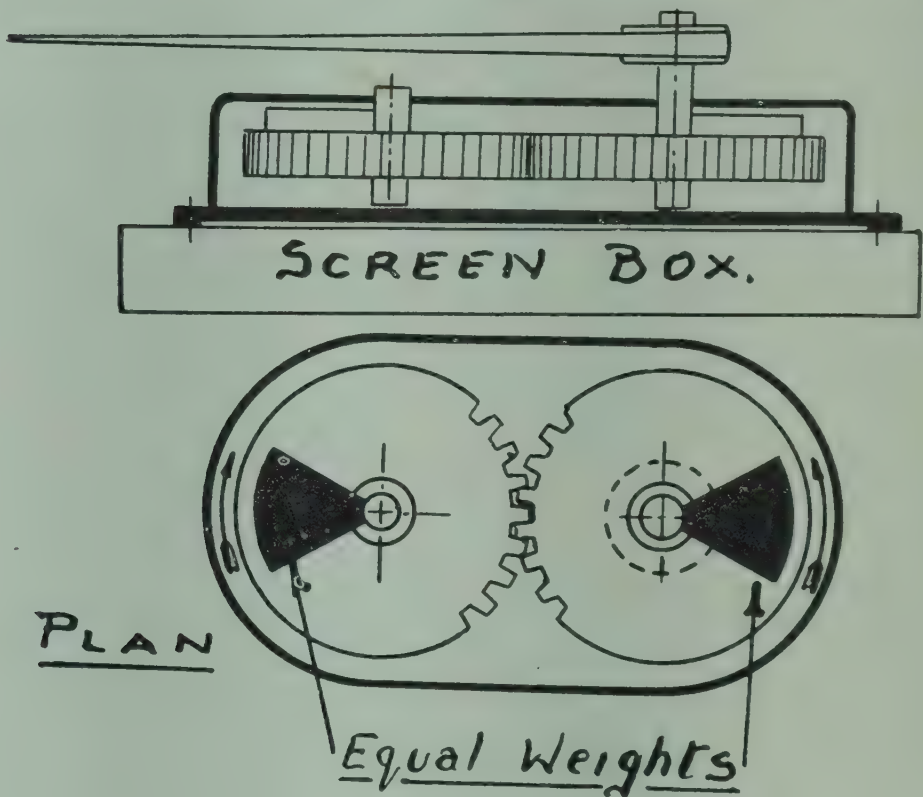


Fig. 107 Juby Drive

(B) and (C) the reaction forces of the weights are acting against each other and cancel out, thus having no effect on the screen tray.

Very similar in principle to the Juby drive is the mono plano drive where a belt driven weighted pulley spindle is fitted with a single helical gear which meshes with an equal gear mounted on a shaft carrying two balanced weighted pulleys. The combined effect of the two weighted pulleys on the second motion shaft is equal to the effect of the weighted pulley on the first motion shaft. As in the Juby drive, the reaction forces balance themselves at some points in the revolution in which position there is no move-

ment of the screen whilst in other positions the reaction forces are balanced only by the movement of the screen element.

The mono plano drive consumes as little as a quarter horse power and is mounted with the pulleys revolving in a vertical plane.

For maximum screening capacity there are limiting factors of stroke length and speed of reciprocation to be considered, and generally speaking, the shorter the stroke length the higher must be the speed. In his book "The Physical Science of Flour Milling," E. D. Simon quotes the results of a series of tests carried out by Messrs. Henry Simon Ltd., to determine the relationship between stroke length speed and screen capacity, from which it appeared that strokes varying between ½ inch and 1 inch yielded similar capacities when driven at appropriate speeds. These speeds varied from about 650 r.p.m. down to 450 r.p.m. These speeds, it should be noted, are optimum

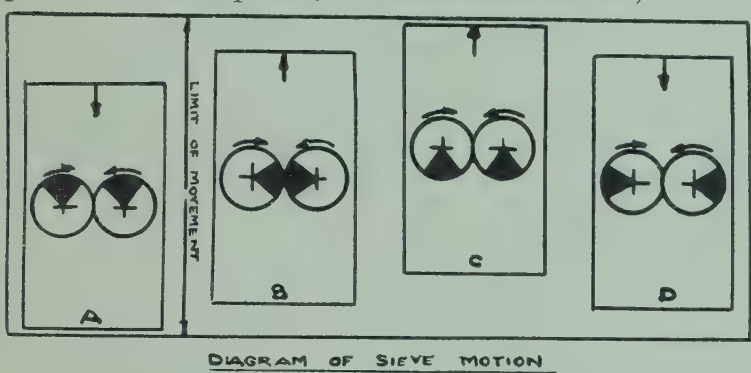


Fig. 108 Movement of Tray Driven by Juby Drive.

speeds, that is, an increase in the figures as well as a decrease in them will result in a falling capacity. There is, however, a modern tendency to move screening surfaces through an extremely small stroke at a very high frequency so that the movement becomes more aptly described as vibration rather than oscillation.

Most of these vibrating screens are mechanically operated by cranks or eccentrics having a very small throw and revolving at velocities up to 1,800 r.p.m., whilst there is a growing range of screens operated electro-magnetically in which the displacement is so small and the movement so rapid that the screen surface appears to be stationary, movement being detected only by the activity of the material being screened. In the electrically vibrated screens the movement is up and down against the load which reduces wear on the screen surface.

The writer is not aware of such high frequency screens having been used for milling separations, and the effect upon milling materials is a matter for conjecture, but in the compound mill at least, there seems to be no reason why such screens should not be usefully applied.

CHAPTER VIII.

SIZE REDUCTION

In an earlier chapter it was pointed out that, but for the facility with which raw materials lend themselves to reduction to a more or less uniform particle size, the mixing of compound foods would be an impossible project. Some materials, it is true, offer considerably more resistance than others to the breaking down process, but no material used in the compound mill is able to withstand the onslaught of modern crushing and grinding machinery. The term uniform applied to the resulting products of the grinding process is, of course, purely comparative, intending only to imply a much closer limit of variation between the size of the particles of the ground materials than between the particle sizes of the materials in the unground condition, e.g., the difference between the size of locust beans and maize, and maize and dried milk powder is obviously very much greater than the difference between the particle size of locust bean meal, maize meal and dried milk powder, although the largest particles of the locust meal would still be considerably larger than the particles of dried milk powder.

Even with any one product the size of particle will vary from the finest dust, capable of passing through a 200's mesh, up to particles which might possibly refuse to pass through a 20's mesh. Within limits of this order of uniformity, the mixing of compound meals is a practical proposition, although the actual maximum size to which the majority of particles should conform may vary with the particular purpose for which the meals are intended. This is a more general form of the statement that materials that are to be used in the manufacture of products which are sold in meal form may need to be ground smaller than materials to be used for the manufacture of cubes.

For compound products, the range of particle sizes in any ground raw material is of little consequence to the suitability of the material, providing that the maximum particle size shall be less than some stated figure, but for other non-compound products like maize grits, for instance, it is desirable that there shall be produced a minimum of very small particles in the size reduction process. Differences of this kind in the requirements of the manufacturing processes may involve the use of different kinds of size reducing machines and the syllabus of this course does in fact nominate four kinds of size reducing machines for the attention of students. These are: (1) Roller mills, (2) millstones, (3) impact (or percussion) grinders, and (4) cutters: the salient characteristics of each of the foregoing were noted in the first year's work.

It has been suggested that the particle size of the required finished product will have an effect upon the choice of a machine to be used for any particular purpose, but it should also be appreciated that the particle size of the material to be fed to the grinder may also have a very considerable influence on the type of machine used and in fact this particular factor may even differentiate between the machines of one family. For instance, the grinding of slab cake involves the use of a machine having a feed opening able to accommodate the size of the cake, which rules out, for instance, a Perplex type machine unless the slab be previously kibbled, but does permit the use of, say, a disintegrator which is in the same broadly classified family of percussion grinders. This grouping of Perplex type machines and disintegrators as impact (or percussion) machines may be subject to some criticism and it may not be inappropriate to leave the main trend of these remarks for a moment to consider the use of the term impact grinder.

One authority has stated that "in an impact grinder the rotor beaters revolve between sets of stationary beaters, whereas in a disintegrator the beaters revolve in an empty casing whose inner circumference is usually corrugated to cause the stock particles to be flung back on to the rotor."

Students should take note of this opinion, but the writer feels obliged to draw students' attention to the following points: Firstly, an impact machine clearly implies a machine in which the material is reduced by a series of blows as different from cutting or attrition. Secondly, it is unfortunate in some respects that the term impact should have been used as a trade name by a particular manufacturer for his make of grinding machine and for this reason it is probably better to use the name percussion grinders when describing the class of machines that reduces by blows. Thirdly, the name disintegrator, whilst popularly used to describe a hammer mill, might in fact be applied to any size reduction machine, that is, disintegrator and grinder are more or less synonymous terms. Even if it is allowed that disintegrator shall be used to describe a machine having beaters or hammers revolving in an otherwise empty chamber, such a machine is still an impact machine in that it reduces the material by a series of blows. In fact, a so-called disintegrator is probably more nearly a true impact machine than the so-called impact machine itself.

Thus, to confine the term impact to a machine having a particular kind of construction rather than having a particular kind of action seems to be a purely arbitrary differentiation. Once the machines have been grouped in families there is no reason, of course, why a further classification should not be made in virtue of the manner in which the machine carries out

the function of its family group, but none of these sub-divisions should be known by a general term like impact which would tend to imply that machines not in that particular sub-division are not impact machines. For an example of this sub-dividing of the family group see page 141 of the first year textbook.

To return to the general consideration of size reduction, it has been said that for compound products the range of particle size below some limiting size in the ground raw material has no effect on the value of the raw material, whereas for other products there may be limits imposed upon the permissible variation in particle size, and that differences such as this will affect the choice of grinding equipment. A further factor which will affect the choice of size reduction machinery is whether the ground product is to constitute a finished product or only an intermediate product (i.e., a product prepared for further processing). With some exceptions, the production of intermediate products is generally a far less critical matter than the production of finished ground products. Two exceptions to this may be noted in :

(1) The cracking of maize preparatory to flaking in which the production of an intermediate product or grits must be accompanied by a medium production of hominy chop.

(2) The grinding of oil cake into a straight meal for sale as such in which there will be no grinding restrictions other than that of maximum particle size.

By far the greatest amount of grinding machinery used in the manufacture of compound foods is used merely to prepare the raw materials for the mixing process, and as the range of particle size and characteristics of those materials is very great, it is only to be expected that compound millers install machines which will handle the greatest possible variety of substances satisfactorily. The family of machines which best meets this need is that of the percussion grinders, of which there are many representatives. For obvious reasons, no attempt can be made to catalogue the details of the dozens of different makes of percussion machines, but the majority of these machines may be allocated to one of three family sub-divisions that have been referred to previously; it must be considered sufficient to study a typical example of each of these classes, although it should be borne in mind that the classification of percussion machines into three sub-divisions is, in itself, a very broad classification and considerable constructional differences may be found between machines which may be grouped into any one sub-division.

Bearing this in mind, consideration may now be given to the first category of percussion machines, that is, the category in which the moving beaters are rigidly fixed to the rotating member and grind the material in a single stage. This

class is chiefly represented by the "disintegrator," in which the beaters or hammers are fastened to or form part of a centre rotor which is mounted on the driven shaft and the example chosen is the "Premier" grinder manufactured by Messrs. George Porteus & Son, Ltd., Leeds, illustrated in Fig. 109, and reproduced from Mr. Leslie Smith's "Flour Milling Technology." Study of the diagram and the key shows clearly that the material to be ground is fed into the "eye" of the machine through the feed chute, and upon entering the grinding chamber is immediately subjected to the hammer action of the revolving beaters which will be responsible for the greatest part of the size reduction. The particles of broken material leaving the hammer path under the impact of the hammers will be projected against the sides and periphery of the chamber. The flying lumps of material which hit the sides of the chamber will thereby receive a second blow which will be directly proportional to the speed at which they hit the side and will be affected by the effectiveness of the braking action exercised by the side plate upon the flying material. That the braking or decelerating action of the side plates will be improved by being corrugated or serrated will be readily appreciated. The material, as well as being reduced by hitting the sides of the grinding chamber, will also be deflected back into the path of the beaters again and this action will tend to repeat itself until the material reaches the screen face in small enough particles to pass through the screen and thus out of the machine. Most of the internal face of the grinding chamber, with the exception of the screen area, is covered with renewable wearing plates which have corrugated or serrated faces. The "Premier" grinder, as well as having a feed inlet into the eye of the machine, also has a back feed inlet and may be fitted with a peripheral feed inlet.

The next class of percussion grinder is described as having beaters rigidly fixed to the moving member, but in which the material is ground in two or more stages. There are a number of machines which are covered by this broad specification, amongst which may be named the "Impact" and the "Perplex." The "Impact" machine, illustrated in Fig. 110, which, again, is taken by kind permission of Mr. Leslie Smith from "Flour Milling Technology," is widely used, but students should not overlook the fact that there are other machines which are covered by the definition of this class of machine as, for instance, the "Perplex" machine. A description of the "Perplex" machine appears in the Seed Crushing Section (part 1, Fig. 31) from which it will be seen that the construction of the machine varies tremendously in detail from that of the "Impact." However, the beaters, or "pins" as they are popularly called, are fixed rigidly to the rotating member and the

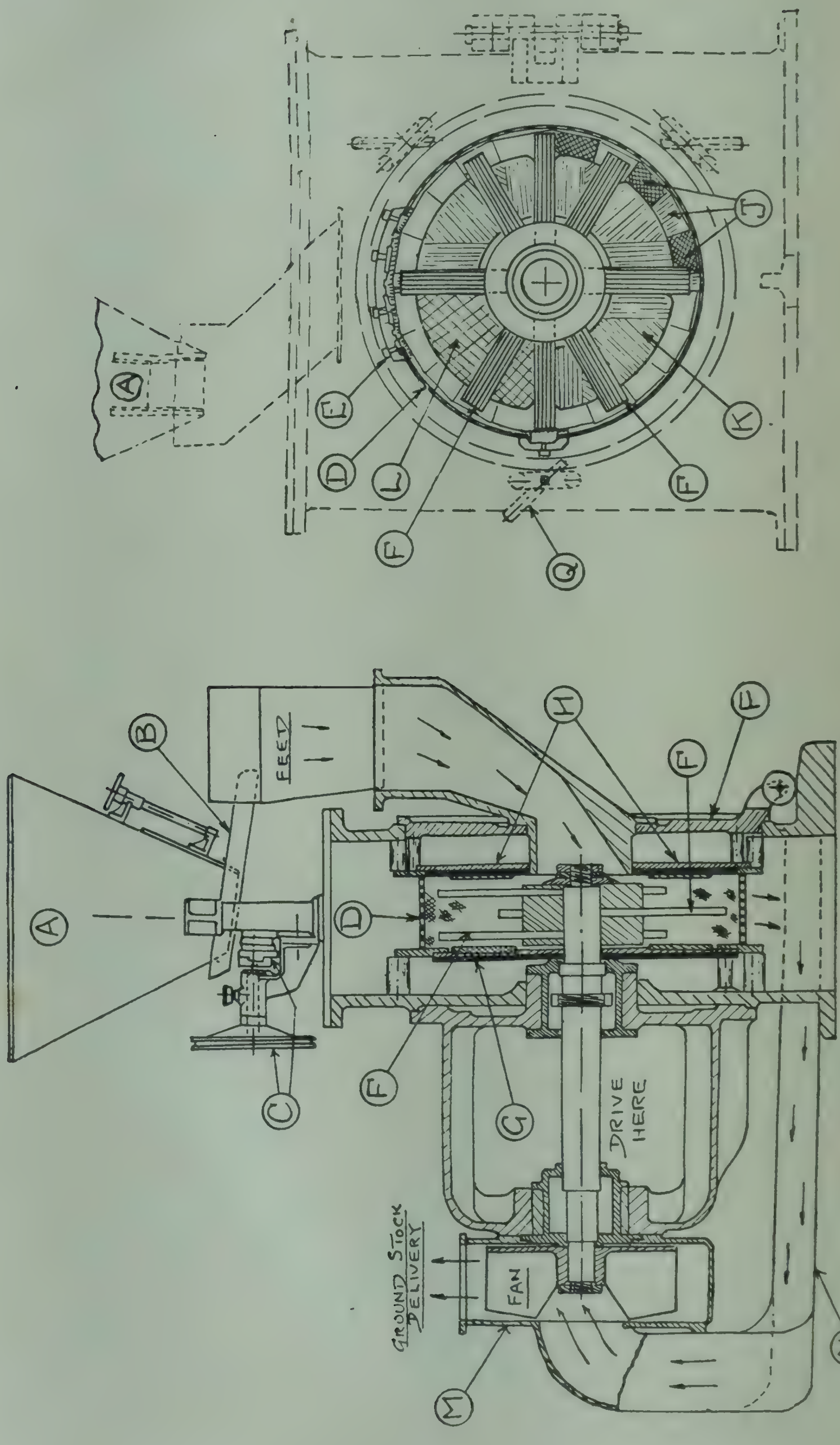


Fig. 109 Porteus Premier Grinder

material being ground passes through three annular grinding chambers before being discharged from the machine. It will be noted, of course, that the escape gap through which the material passes from one chamber to the next in the " Impact " machine is located in one part of the periphery of the inner chamber, (although later designs of this machine omit this gap), whereas in the " Perplex " machines it is distributed around the whole periphery of the inner chambers. Thus, the chamber wall is composed of a series of fixed pins of similar pattern to the moving pins and between which the material may pass at all points.

It may be noted that earlier versions of Messrs. W. S. Barron's " Impact " grinder did not have the four hammers as shown in Fig. 110, nor was the gap between the inner and outer chambers confined to one part of the periphery and, in fact, the earlier " Impact " machine is very similar to the " Perplex " machine.

Fig. 109 **Porteus Premier Grinder (Page 186)**

Key to diagram: (A) Feed hopper. (B) Shaker feed tray. (C) Eccentric mechanism operating the feed tray. (D) Periphery screen. (E) Screen holder, with fluted pads attached to aid attrition. (F) Serrated flying beaters, grinding the stock against the fluted and serrated surfaces and driving the stock through the periphery screen. (G) Stationary back ring, with serrated pads attached. (H) Stationary front ring, with serrated pads attached. This secures the screens in position and is detachable. (J) Serrated pads on the front and back rings. (K) Additional serrated pads on the back ring. (L) Wire sieve (for air) on the front and back rings. (M) Fan body. (N) Suction trunk from underneath the screen to the fan. (P) Swing door to permit access to screen cover and beaters. (Q) Locking handles to secure swing door to frame.

The third sub-division of the family of percussion machines includes all those machines in which the beaters are pivotted to the rotating member in such a manner as to permit them to swing through a limited arc in the plane of rotation. Machines of this class, often referred to as hammer mills, or more precisely as swing hammer mills, are rapidly becoming amongst the most important grinding machines for compound mill purposes.

The larger sizes of swing hammer mills usually have a feed opening capable of accommodating the normal sizes of slab oil cake without any previous reduction, and are able to grind the cake to a fine meal in a single operation without excessive demands on mill space or power as well as being able to give a passable performance on the grinding of cereals. The smaller types, when fitted with an automatic feeder, and particularly when fan exhausted, will grind cereals for mixing purposes very satisfactorily.

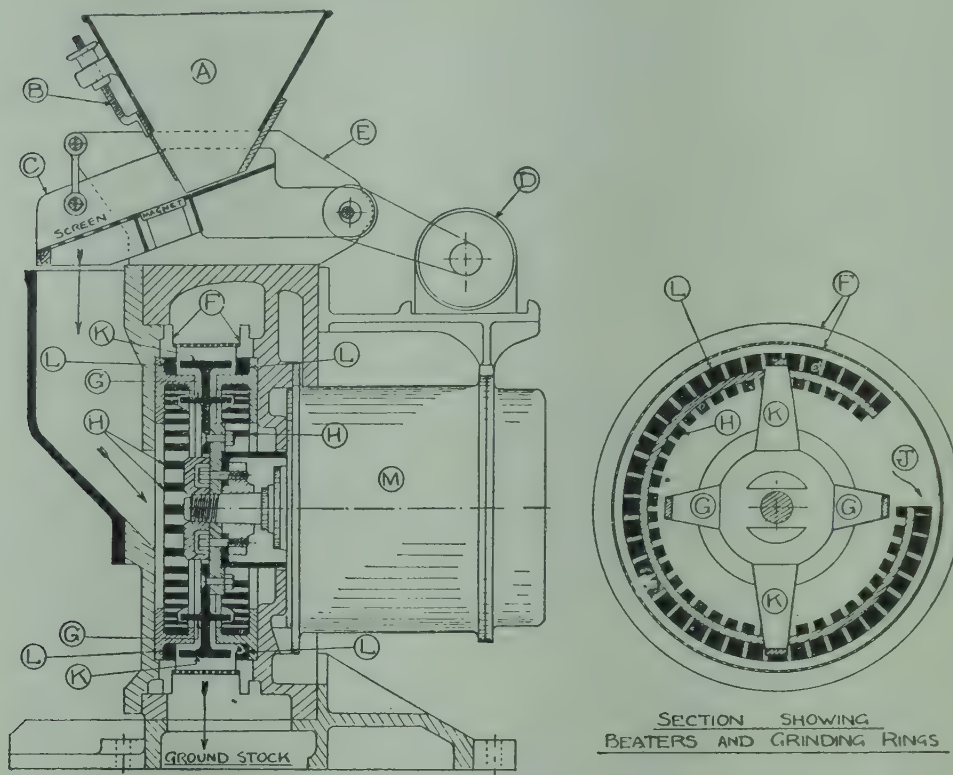


Fig. 110 **Barron Impact Grinder**

Key to diagram: (A) Feed hopper. (B) Slide with screw adjustment to regulate the feed opening. (C) Feed shaker, provided with a coarse screen to overtail large material. This shaker, suspended from the frame E, is reciprocated by a separate motor operating an eccentric shaft. (D) Small motor driving feed shaker. (E) Frame, housing feed shaker. (F) Screen and screen ring. The screen extends right round the grinding rings. All ground stock passes through the screen and is designed to assist in reducing the stock. (G) Two inner beaters—rapidly revolving. (H) Stationary inner grinding ring. The inner beaters G, working against this inner ring, give a preliminary kibbling to the stock and then drive it through the opening shown at J into the grinding chamber proper. (J) Opening to grinding chamber proper. (K) Two outer beaters, grinding the stock against the outer grinding ring L and the screen, through which it is forced when sufficiently reduced. (L) Stationary outer grinding rings. (M) Built in motor driving the beaters (on No. 2D type of machine this is a 20 h.p. motor running at 3,000 r.p.m.).

As a representative of the swing hammer mills, the Christy & Norris swing beater pulverizer is illustrated in Fig. 111. This machine is of the type having a feed opening large enough to receive slab oil cake, and as will be seen, the lower half of the chamber periphery is composed of screen surface. The screens may be perforated metal or may be frames fitted with bars. In the upper part of the grinding chamber may be fitted breaker blocks as shown, and the function of these blocks will be discussed later. The incorporation of a metal trap in the design illustrated should be noted. This metal trap receives odd pieces

of tramp iron which may find their way into the machine, the iron being projected into the box by the revolving beaters.

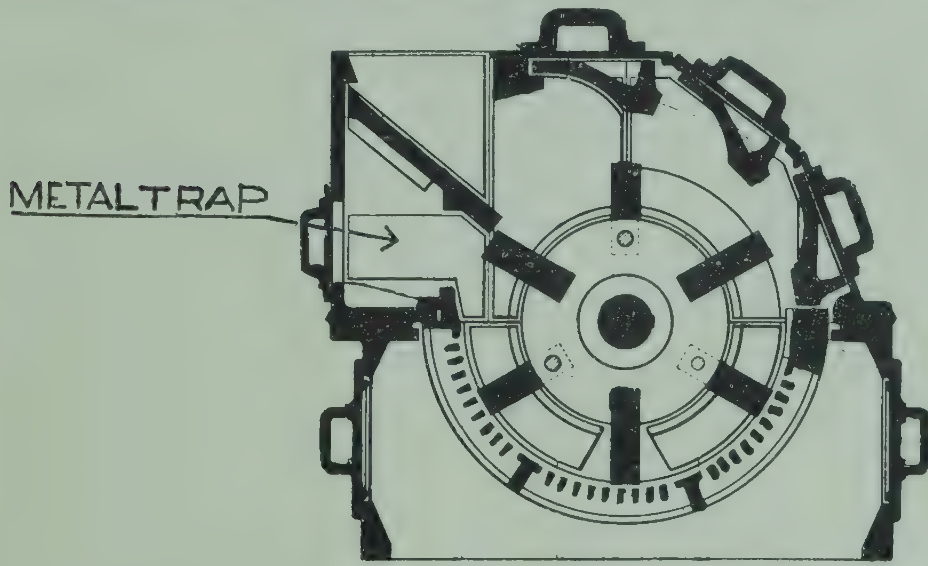


Fig. 111 Grinder Cross Section showing Metal Trap

Swing Hammer Mills

The position of the beaters in a swing hammer mill is usually capable of being altered so that the clearance between the tip of the revolving hammers and the screen surfaces can be made greater or smaller. Generally, the miller has a choice of three positions and he will normally fix the beaters in that position which gives the greatest beater tip clearance, for this results in a reduction in power for any given output, within the limits prescribed by the construction of the machine.

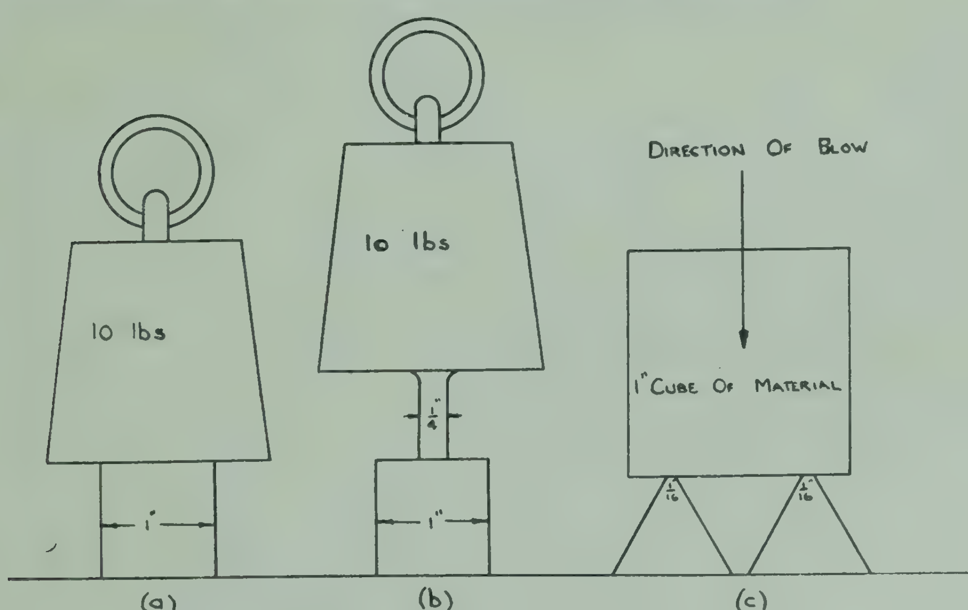


Fig. 112

A variety of hammer types is available, some having a most elaborate form, but it is doubtful if any advantage is derived from the use of so-called multi-edged beaters. A plain beater suitable for use in the swing hammer mill already illustrated would be 6½ inches long × 2 inches wide × 1 inch thick and have a hole in one end to accommodate the spindle or pin upon which the beaters are mounted. Manganese steel is a favourite material from which to make such beaters because of its work hardening properties, that is, the surfaces of the material become harder under the effect of load, but it is doubtful if the load on the beaters is sufficiently heavy to invoke this work hardening characteristic before critical wear has actually taken place. Toughness is a pre-eminently desirable characteristic but

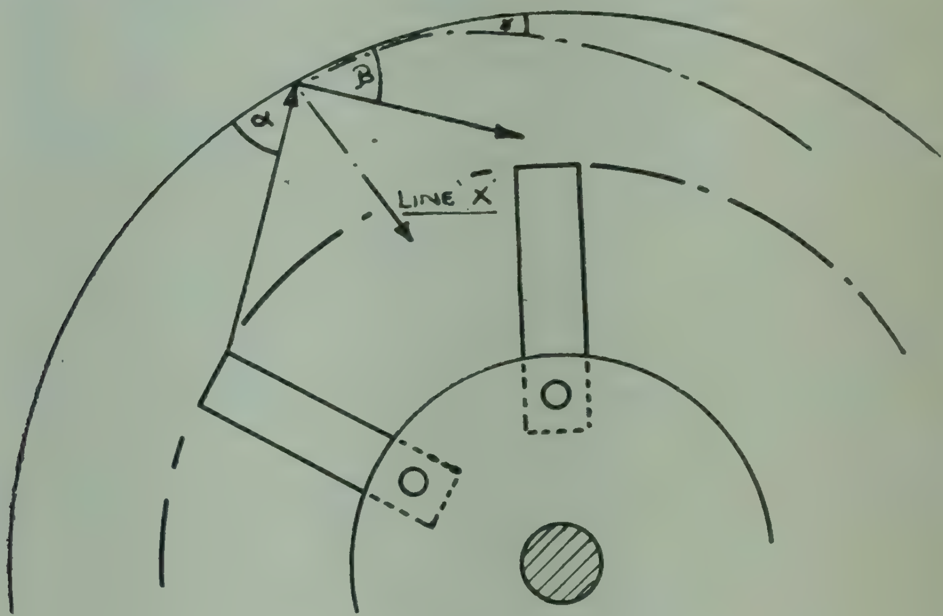


Fig. 113

must be combined with sufficient elasticity to withstand shock loading, and this latter requirement subjects cast steel beaters to some suspicion. Some of the low alloy steels have proved to be very suitable materials for beater manufacture and lately, beaters having cemented carbide tips have been tried.

Swing hammer mills, as indeed all grinding machines, should receive as steady a feed as is possible, for only under this condition will the machine give its best performance. Some difficulty may be experienced in maintaining a constant feed to those machines which are used to grind slab cake in one operation and it is customary to put a flywheel on the rotor shaft of such machines. The function of the flywheel is to store up energy when the machine is running light, so that a reserve of power may be available when cakes are suddenly dropped into the path of the beaters.

A modern practice is to exhaust grinding machines, and swing hammer mills are increasingly found fitted with a fan as an integral part of the machine. The fan, apart from increasing the throughput of the machine, enables damp materials to be ground which would otherwise blind the screen perforations, makes for cooler grinding and often serves as an elevator to lift the ground material to a sacking off point several floors above the machine. One of the incidental advantages of fan exhausted machines is that they can be installed upon a ground floor without having a hopper and elevator boot located in the basement or pit underneath the machine to receive the ground material.

Many manufacturers of percussion grinders claim that the serrated wearing pieces fitted both in the periphery and the sides of their machines improve the frictional or attrition grinding. This may in fact be the case, but the writer believes that any attrition effect resulting from the use of serrated chamber liners or beaters is purely incidental and is, in fact, not a particularly desirable feature in this class of machine. That some rubbing or attrition is unavoidable is, of course, true, but the proper function of serrations cut in chamber linings, seems to be twofold; firstly, to create local stress intensities in the material being ground, and secondly, to increase the effect of the hammer blows by increasing the relative velocity between the material and the hammers. This may sound rather academic but consideration of the following should make the points clear.

Firstly, as to local concentration of stress; students will be familiar with the conception of stress as being measured by dividing the load which is acting on any given object by the area of the object over which the load is acting, e.g., a load of 10 lb. resting on a cube of material of 1 inch side in such a manner that the whole of one face (Fig. 112a) of the cube is in contact with the load will induce a stress in the material of 10 lb. per square inch. If, however, the area of application of the load should be reduced to, say, $\frac{1}{4}$ inch square (Fig. 112b) on the face, the stress at the point of application of the load now becomes 10 lb. divided by the area of the $\frac{1}{4}$ inch square which equals 10 lb. per $\frac{1}{16}$ inch of a square inch which is equal to

$$\frac{10 \times 16}{1} = 160 \text{ lb. per square inch.}$$

Consider now a flat face inside a grinding chamber against which a cube of material is flung by the revolving hammers with a force (F); if the cube is of 1 inch side, then the stress in the material will be equal to F lb. per square inch.

Now, suppose the same cube of material is flung against a serrated face having serration with, say, a $\frac{1}{16}$ inch land (Fig. 112c), then clearly the stress will now be spread over an area of

two serrations in the example shown, each having an area of 1 inch × $\frac{1}{16}$ inch = $\frac{1}{8}$ square inch, and the local stress in the material is now 8 F lb. per square inch. This treatment ignores all questions of bending stresses in the material which, however, serve to increase the effectiveness of the serrated surfaces.

Secondly, the increase in the effect of the hammer blows due to an increase in relative velocity between the hammers and the material being ground. The actual velocity of a body is always referred to a point which is stationary relative to the earth and it may in fact be some point on the earth itself, as in the case of a moving vehicle. The velocity of a moving object may be viewed from the point of view of another moving object, however, as, for instance, two motor cars proceeding in the same direction at the same speed would appear from each other's viewpoint to be stationary, that is, the relative velocity between them is nil. If one of the cars was travelling at 40 m.p.h. and the other at 30 m.p.h. then their relative velocity would be 10 m.p.h. Similarly, if the two cars were proceeding in opposite directions at the speeds mentioned, viewed from each car's point of view the other would appear to have a velocity of 70 m.p.h., from which it will be seen that the direction of the moving bodies is important.

Consider now (Fig. 113), which indicates the rotor of a hammer mill and the inside of the grinding chamber. Material propelled by the hammers hits the inside of the chamber and bounces off. In the absence of skidding, the angle at which the material bounces back (B) will be similar to the angle of approach (X); should skidding occur, however, the angle at which the material leaves the wall of the chamber will flatten out to say (C). The effect of this is that the velocity of the particle after skidding will approach more nearly to the direction of the velocity of the beaters, so that the effective velocity of impact between the two will be reduced by the velocity of the particle.

Suppose now that the particles of material always rebounded from the grinder wall in a direction at right angles to the path of the beaters, line (X) (Fig. 113), then the speed of the particle would have no effect upon the velocity of impact. Serrated surfaces help to return the material back into the beater path in a direction more nearly approaching that shown by line (X) in Fig. 113 than do plain surfaces. Breaker blocks of the type shown in Fig. 111 deflect the material back into the beater path and do so more effectively than so-called attrition plates. High attrition means high power, and if a percussion mill is not being overfed, attrition will be a minimum. If the required product can best be produced by attrition, then resort should be made to attrition machines.

Attrition Mills

The origin of the reduction of materials by attrition is lost in antiquity, but a clear line of development may be traced from early stone mills to modern metal disc grinders. Stone mills, having the stones revolving in a horizontal plane, have given way largely to mills having the stones mounted in vertical planes with one stone fixed and the other revolving. Some loss in the appearance and texture of products from vertical stones may be found when compared with the products of horizontal stones, but this is not likely to be of importance to present day provender millers and can be completely disregarded by compound millers in the face of the advantages offered by vertical stone mills.

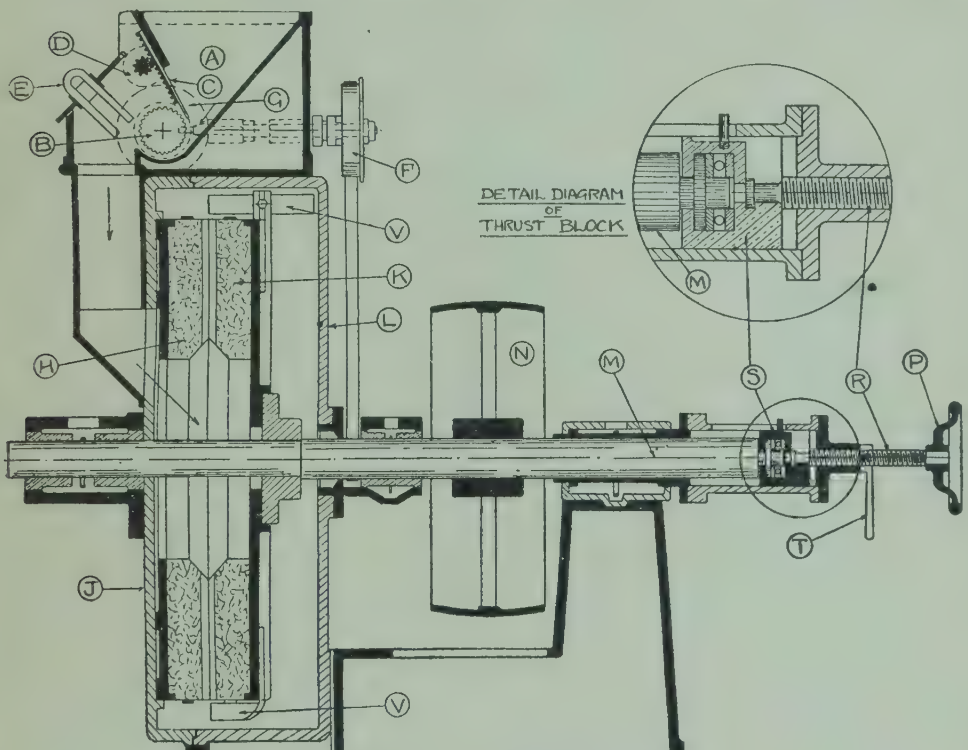


Fig. 114 **Dreadnought Grinder**

These advantages may be summarized as:

(1) Considerably larger capacity for any size of stone, chiefly arising from higher running speeds.
(2) Driving a horizontal shaft is usually very much more convenient than driving a vertical shaft.
(3) The feeding arrangement is considerably better than that of the horizontal mill.
(4) More compact.
(5) Usually simpler furrow pattern which, with composition stones, leads to easier stone dressing.

A popular vertical stone mill is the Dreadnought grinder of Messrs. W. S. Barron & Son Ltd., the accompanying illustration of which (Fig. 114) is taken from Mr. Leslie Smith's " F.M.T."

A later development of attrition grinding is the substitution of chilled iron plates for the stones, chiefly to increase the life of the wearing faces and to eliminate the skilled dressing which stones require. Apart from the substitution of iron for stone, the design of the grinding machines may be very similar; for instance, the Dreadnought grinder is made in two patterns, one of which is fitted with stones and the other with metal grinding faces (although the makers specifically recommend the use of the metal discs for the grinding of materials not used in the feeding stuffs industry'.

A popular type of metal disc mill is the Turner " Inkoos " mill, much used by farmers, corn merchants and smaller millers, but hardly big enough for large scale industrial usage for which purpose Messrs. E. R. & F. Turner Ltd. manufacture their

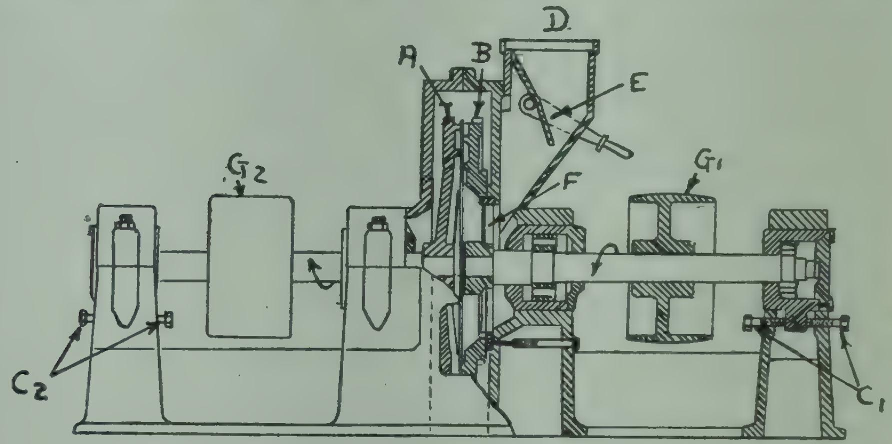


Fig. 115 " Macrof " Mill

(A) & (B) Grinding discs.
(C1) & (C2) Set screws for axial adjustment of discs.
(D) Feed opening.
(E) Adjustable feed gate.
(F) Inclined spokes.
(G1) & (G2) Belt pulleys.

" Macrof " mill (Fig. 115). This machine has both discs revolving in opposite directions and the discs are capable of adjustment axially, thus allowing the clearance between them to be set to suit any particular grinding circumstances. One of the discs is connected to its hub mounted on the driving shaft by a number of inclined spokes which receive the feed and propel it into the space between the discs. The discs revolve in a chamber formed by two half chamber castings to one of which is attached a feed spout having a control gate.

The normal range of speed for discs of these machines is from 1,500 to 2,500 r.p.m., giving a relative velocity between discs of from 3,000 to 5,000 r.p.m. The chilled iron grinding discs are patterned with various designs of furrows or corrugations, and if the machine is adequately fed, the principal reduction in particle size is achieved by attrition, although there is always likely to be some impact grinding occurring, particu-

larly with light feeds. A high power consumption is almost always a characteristic of attrition grinding, and the difficulty of preventing escape of material from the grinding area until it has suffered some particular reduction in size makes the achievement of consistent particle size difficult. These machines are considered to operate most successfully on hard grain like maize.

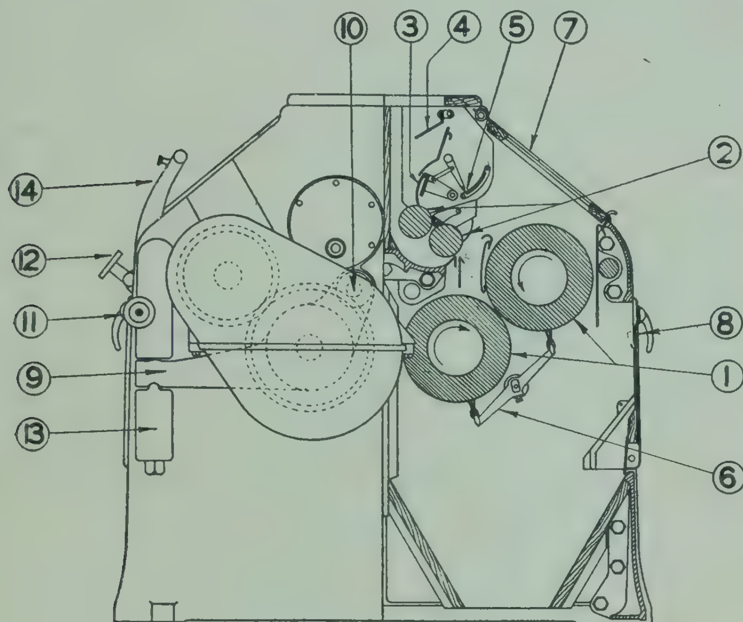


Fig. 116 Roller Mill

(1) Roll body.
(2) Fluted feed rolls.
(3) & (4) Interconnected feed plates —movement of 4 under feed communicated to 3.
(5) Pointer and scale for use with non-automatic operation.
(6) Brush scrapers for roll cleaning.
(7) & (8) Inspection doors.
(9) Pivotted arm carrying lower roll.
(10) Pivot of (9).
(11) & (12) Position control for adjustable roll.
(13) Spring to allow rolls to part in the event of obstruction.
(14) Throw-out lever for quick release of rolls and cutting-out feed.

Roller Mills

With fully furrowed stones, a fair proportion of the reduction in a buhrstone mill is the result of the cutting action of the furrow edges as the material is caught between two furrows crossing each other scissor fashion. With a bottom running stone, the material is fed against the top stone cutting edges by being held in the furrows of the revolving lower stone; with the top stone running, the lower stone tends to hold the material in its furrows whilst the top stone cutting edges are brought to bear against it. This action is the basis of roller mill reduction, with the advantage that the attrition which necessarily occurs between flat stone faces is almost completely avoided with a pair of fluted rolls, as the working area at any particular

instant is confined to the immediate vicinity of the flutes which are gripping the material, within which area the action is almost completely cutting.

The roll faces, which are in contact with the feed, are travelling in approximately the same direction and, in fact, at the position of the common centre line joining the rolls, the faces are travelling in exactly the same direction. In order to

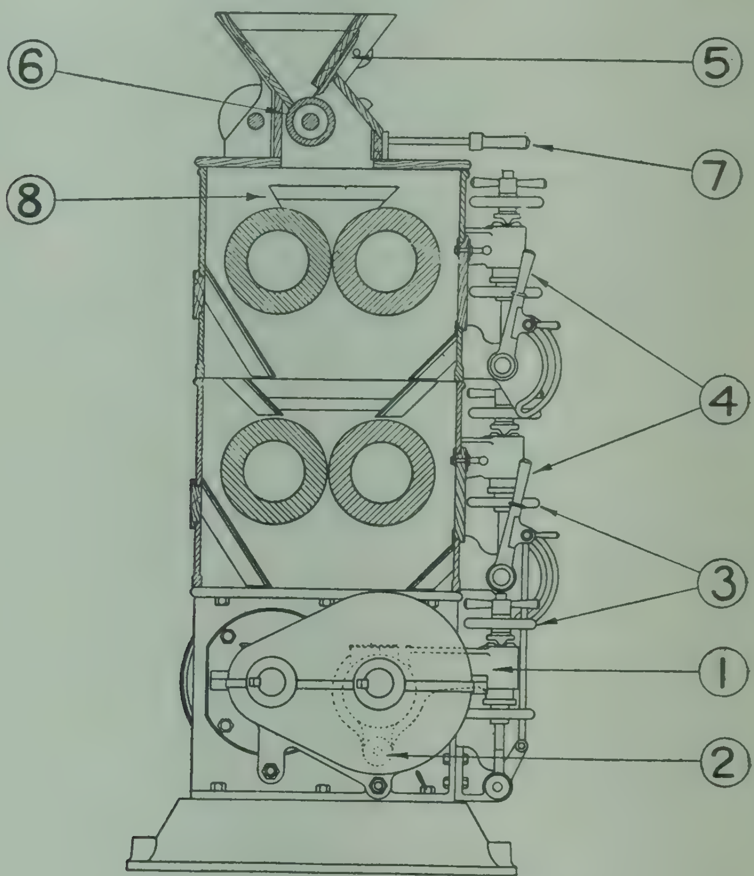


Fig. 117 Three High Roller Mill

(1) Movable roll arms.
(2) Pivot of 1.
(3) Roll positioning control.
(4) Throw-out levers for quick release.
(5) Feed slide.
(6) Feed roll.
(7) Feed roll clutch control.
(8) Sieve.

obtain a cutting action, it becomes necessary that one of the faces shall travel faster than the other, which accounts for each roll of a pair being run at a different speed from the other. The sharp edge of the flutes in the faster roll operates in the direction of rotation, whilst the sharp edge of the slow roll flutes operates against the rotation. This arrangement is necessary so that the material may be cut between the sharp edges passing each other. It is customary to consider that the slow roll holds the material whilst the fast roll does the cutting, but it is conceivable that

some of the material may be carried by the fast roll against the cutting edge of the slow roll flutes, in which case the fast roll could be considered to be the holding roll. The scissor effect noted in stone mills is obtained in the case of roller mills by cutting the flutes in slow spiral along the length of the roll, the spiral being the same hand in each roll. A common speed difference between rolls is $2\frac{1}{2}$ to 1, although this may be varied to suit particular circumstances, as also may be the angle of the spiral which, for most purposes, is about 1 in 6 or 7. A roll size of 10 inch diameter by a length of 40 inch is used in the diagonal roller mill illustrated in Fig. 116, whilst rolls either 7 inch or 9 diameter by 16 inch to 24 inch long are found in the horizontal roller mill (Fig. 117).

It should be noted that the diagonal mill (Fig. 3) is really composed of two separate and distinct mills, back to back, and contained between a pair of common end frames, which arrangement is not nearly so convenient as a multiple pair horizontal mill for large reductions in one machine. For efficient working, it is imperative that the feed to roller mills shall be evenly distributed along the length of the roll, and feed rolls or other feeding devices are essential features.

CHAPTER IX.

MIXING

The satisfactory mixing of the ingredients of a compound meal, whilst clearly of basic importance to the whole process of compound food manufacture, is an operation about which less theory can be stated than almost any other operation in the mill. As in all physical operations, there is a time factor, and in batch mixing this factor has a noticeable effect upon results. In continuous mixing also, there is a minimum period of time for which the ingredients must be mixed together, but the effect is not so noticeable because of the fact that for continuous mixing, the ingredients must be fed into the mixing system in properly proportioned parallel streams, whereas for batch mixing they may be fed consecutively.

In its most elementary form, batch mixing would consist of depositing the required ingredients upon a floor in the required quantities and mixing them together with a spade, much in the same manner that concrete might be mixed. The shovelling process would stop when it had been decided that a satisfactory mix had been obtained, and the material would then be passed on to the next process. There can be no doubt that, in the past, hundreds of tons of meal have been mixed in this fashion.

A workman with a spade is capable of producing a very high standard of intimacy of mixing, a standard which is probably

not exceeded by any mechanical contrivance. A workman with a spade may be considered as a mixing machine having stirrer blades with powers of discrimination, and thus able to apply their energies where they are most needed. The workman might first mix together the materials in pairs and then mix the pairs together, and so on, until all the ingredients were contained in one heap, or small quantities of all the ingredients might be mixed together simultaneously. To mix, say, eight or nine ingredients in a ton mixing altogether in one heap robs the manual system of its effectiveness, as determination of optimum mixing point would be difficult.

From the point of view of cost and working conditions, manual mixing is primitive, and on these two counts must give way to machine mixing, but it must not be thought that a machine will necessarily produce a better or even as good a mixing.

To refer to one mixing being as good as, or better than another, clearly involves a standard of differentiation. This standard, as far as intimacy of mixing is concerned, must be in terms of the smallest quantity of the mixing in which all the ingredients shall be present in their proper proportions. The highest standard would be represented by a mixing which met the above conditions in a sample consisting of as many grains as there were ingredients in the mixing. To make such a mixing possible, even arithmetically, would clearly require that each ingredient in the mixing shall contain an equal number of grains. Such a standard is completely impractical, but students should note the implication that those ingredients which are present in small quantities in the mixing need to be more finely subdivided than those materials which are present in larger quantities.

In determining the standard to which he is to work, the miller will first ask the question : " How small need the perfectly homogeneous sample be and, secondly, how small is it possible to make it?"

It is in the miller's interest that the sample, which must contain all the ingredients in their proper proportions, shall be as large as possible, but the actual size of the sample must be decided ultimately by the veterinary dieticians. A normal practice in a particular mill might be to draw a sample of, say, ½ lb. of cubes from the mill at intervals and analyze the cubes. Now, ½ lb. of, say, ½ inch diameter cubes would probably consist of about 70 cubes, so that in this particular case the mixing has to be such that, in a 70 cube sample, the ingredients shall all be present in proper proportions. On the other hand, a user might expect that every cube shall have all the ingredients in proper proportions, and this represents a different standard of mixing.

The fixing of the mixing standard will affect the methods

of mixing and, therefore, must be decided upon at the outset, for it is uneconomic to adopt standards higher than the product calls for.

Reverting now to the man with a spade, he can produce possibly the highest standard of mixing, in fact, a standard which is higher than it need be. By reducing the time he spends in mixing a batch, the man will produce, in a given time, more mixed meal of a lower but perfectly adequate standard of mixing; a standard which can be emulated by machinery.

The first stage in mechanical mixing is the use of a machine to mix a batch of ingredients fed into it manually. The batch of ingredients would remain in the machine for a length of time determined by the standard of mixing adopted, at the end of which time the mixed batch would be discharged.

The next step in mechanization would be to feed the mixer mechanically. As a batch mixer has to be fed in batches, fairly elaborate control of the feeders would be necessary, particularly if they are operated automatically. The control of feeders or proportioning devices would be easier if the need for stopping and starting could be avoided, i.e., if they could operate continuously. This condition would require continuously operated mixing plant, and as has been stated, continuously operated mixing plant needs to have each ingredient streamed into it in such a way that the smallest ingredient takes exactly as long as the largest ingredient to enter the mixing system. This condition of parallel proportioned streams can be achieved, but not without some difficulty, so that the probability is, at the present time, the majority of millers feed their mixing systems upon the batch principle, although the biggest part of the country's compound tonnage is probably mixed continuously which, of course, means that the big mills use the continuous method. By the proper use of intermediate bins, the batch fed mixing unit may be arranged to deliver a continuous stream of mixed meals to the succeeding processes.

Little dissention arises about the actual mixing of the meals but much divergence of opinion arises over the most satisfactory method of proportioning. The first point to be settled is whether the materials are to be proportioned by weight or by volume. On the side of the weight school of thought, it must be admitted that there will be greater accuracy but, on the other hand, supporters of the volumetric method may claim that the accuracy of weighing is greater than the product requires and that the accuracy of volumetric proportioning is perfectly adequate.

The second point to be decided is whether the proportioning shall be manual or mechanical, and the variety of mixing systems arising from combinations of decisions about these two points are covered by the following list :

(1) MANUAL PROPORTIONING BY WEIGHT IN BATCHES (Fig. 118/(1a), (1b).).

This may be represented by (a) men tipping weighed bags of materials into a batch mixer, or by (b), tipping materials into a weigher hopper feeding a batch mixer.

(2) MANUAL PROPORTIONING BY WEIGHT CONTINUOUSLY (Fig. 118/2).

This may be represented by men tipping weighed bags of materials continuously into a receiving hopper feeding a continuous mixer.

(3) MANUAL PROPORTIONING BY VOLUME IN BATCHES (Fig. 118/3).

This is the same operation as (1), except that materials are not weighed prior to mixing but are mixed by assumed weights of materials contained in definite size of bags with periodic weigh checks on the accuracy of assumption.

(4) MANUAL PROPORTIONING BY VOLUME CONTINUOUSLY (Fig. 118/4).

The same operation as (2), but here again the proportioning is in terms of bagsful rather than cwts. although obviously a bagful represents so many cwts., but each bagful is not actually weighed.

In all the mixing systems involving the tipping of bags in definite proportions, a very real source of error arises from the necessity of the man tipping the bag having to tip quantities involving any fraction of a bag. To judge half a bag may be feasible, but to judge any other fraction is clearly a most chancy business and impossible from the point of view of consistency.

All the foregoing systems, with the exception of (1B), are subject to this criticism, but over any reasonable period of working or some minimum number of tons of mixing, inequalities will average out and it will depend upon the standing of mixing desired whether or not the criticism is completely damning.

(5) MECHANICAL PROPORTIONING BY WEIGHT IN BATCHES (Fig. 118/5).

All systems having automatically fed and discharging weighing machines which discharge in batches come into this category, even though they may be feeding continuous plant. It should be noted, however, that in broad terms, when referring to the complete proportioning and mixing process, where such batch weighers are discharging into continuously operating mixers the whole plant is referred to as an automatic continuous plant. This custom does not alter the fact that the proportioning is a batch operation, however, and does not provide coincidental proportioned *streams* of materials.

(6) MECHANICAL PROPORTIONING BY WEIGHT CONTINUOUSLY (Fig. 118/6).

Perhaps the only system which truly belongs to this category is that in which short conveyor bands feeding the materials are suspended upon weighbeams and controlled in such a way that the actual flow of the material is weighed (refer to Fig. 85 in the first year textbook).

(7) MECHANICAL PROPORTIONING BY VOLUME CONTINUOUSLY (Fig. 118/7).

This may be represented by any of the continuously discharge volumetric measurers as, for example, the "Smith" feeder or the "Simon" measurer feeder, or any bin discharger affording control of the flow.

Fig. 118 shows typical diagrams of the various types of mixing stages enumerated previously.

Sketch (1a) and (1b) show manual proportioning by weight in batches.

Sketch (2) shows manual proportioning by weight continuously.

Sketch (3) same sketch as (1) proportioning by volume in batches.

Sketch (4) same sketch as (2) proportioning by volume continuously.

Sketch (5) mechanical proportioning by weight in batches.

Sketch (6) mechanical proportioning by weight continuously.

Sketch (7) mechanical proportioning by volume continuously.

The actual plant used to carry out any of these operations is open to wide variations, although there is a marked tendency towards a limitation of variety in the operating principles of many classes of machines, particularly within the confines of any single industry. Mixing machines provide a good example of this limitation of types within a particular industry, and whilst there are a great number of different types of mixing machines, the feeding stuffs industry limits its principal choice to the Horizontal trough and the Fountain types among the batch mixers, with a possible second choice of the Globular mixer (Fig. 119), and in continuous mixers, the simple kettle, the Duplex worm (Fig. 120), and the Cascade mixer (Fig. 121).

The Sizer Globular mixer, as shown in Fig. 119, is fitted for the mixing of molasses into meals. The auxiliary equipment shown consists of a steam heated molasses tank and a heat insulated measuring tank which discharges its contents upon a finely perforated tray, through which the molasses is fed on to the meal. When mixing is complete, the batch is drawn off through a slide-controlled opening in the bottom of the mixer.

Most batch mixers have the mixing arms or blades revolving within a range of from 20 to 40 r.p.m., with a batch mixing time of from 10 to 20 minutes. An attempt to shorten the mix-

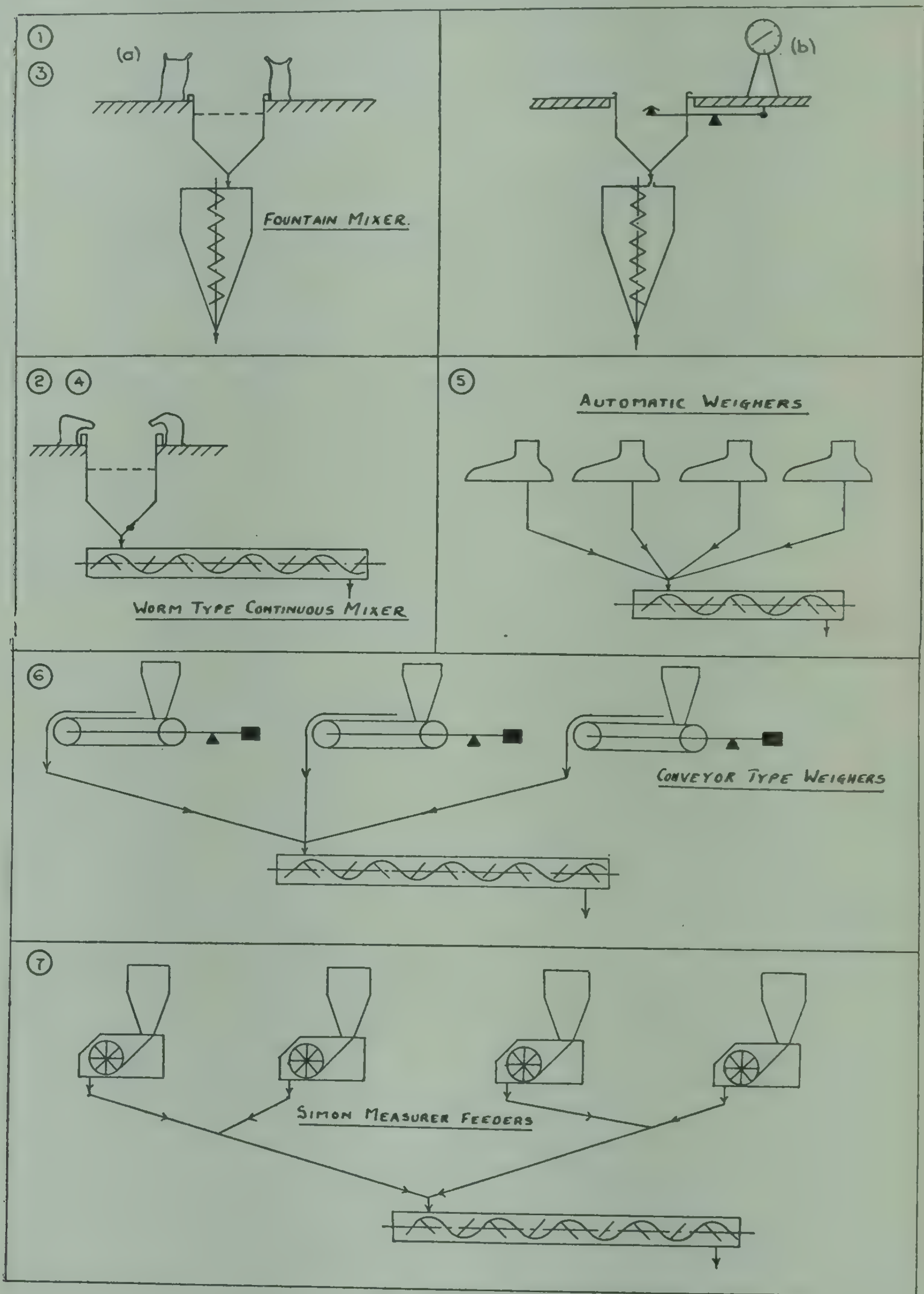


Fig. 118 Various types of mixing stages

ing of a batch by increasing the speeds of the mixing arms is almost certain to fail, and even if some reduction could be obtained, its cost in power would be excessive.

Continuous mixers, on the other hand, usually operate at much higher speeds; the Duplex mixer, for instance, has a

shaft speed between 200 and 300 r.p.m. The small quantity of material in the mixer at any one time makes the higher speeds obtainable without excessive power requirements. With rotating mixing members, care must be taken that speed increases do not in fact result in a tendency to separate the materials rather than to mix them. The centrifugal forces set up in revolving bodies are utilized in many industries to effect a separation of materials. With small differences in particle weights, however, very high speeds would be necessary to make a noticeable separation. Students should not forget, however, that this separating tendency exists at the slowest speed and

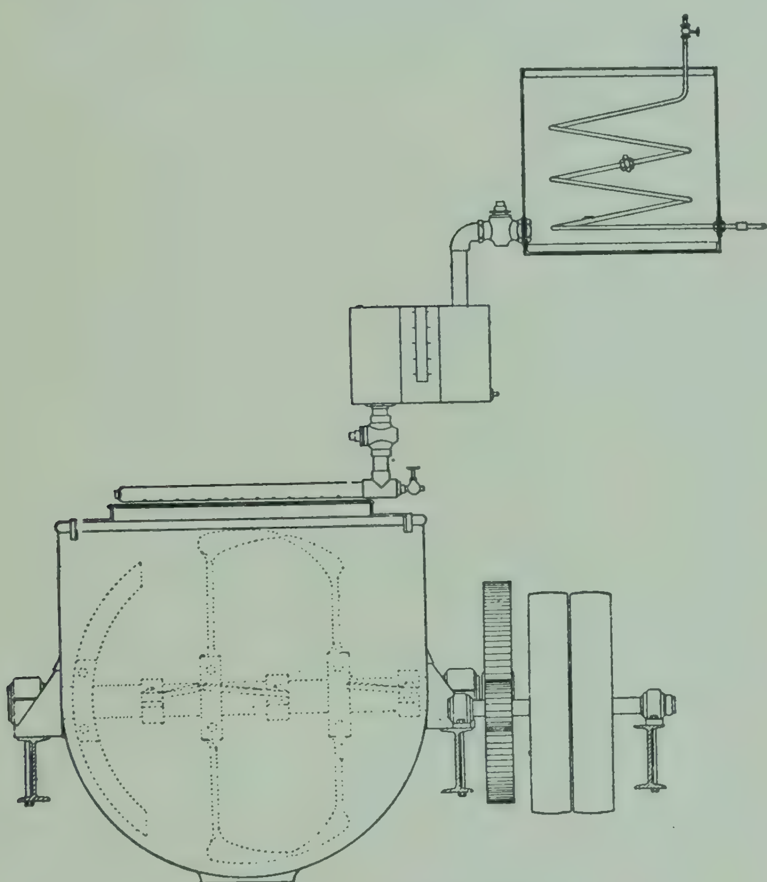


Fig. 119 **Globular Mixer**

the slightest difference in particle weights, but that in all successful mixing machines the mixing effect is tremendously preponderent. The design of the mixing arms varies from simple, flat or angle lifters to elaborate helix blades.

Proportioning devices are as varied as mixers. In the scheme shown in Fig. 118 (sketch 2), the proportioning device is, of course, the mill operative, and the hopper into which he is tipping the materials may be circular or rectangular in shape. If rectangular, a tapering worm should traverse the length of the hopper bottom and the worm will discharge from the whole

length of the hopper rather than from one part, and thus maintain the proportioning obtained by the selective tipping of the bagged materials, which is, of course, not of a very high standard.

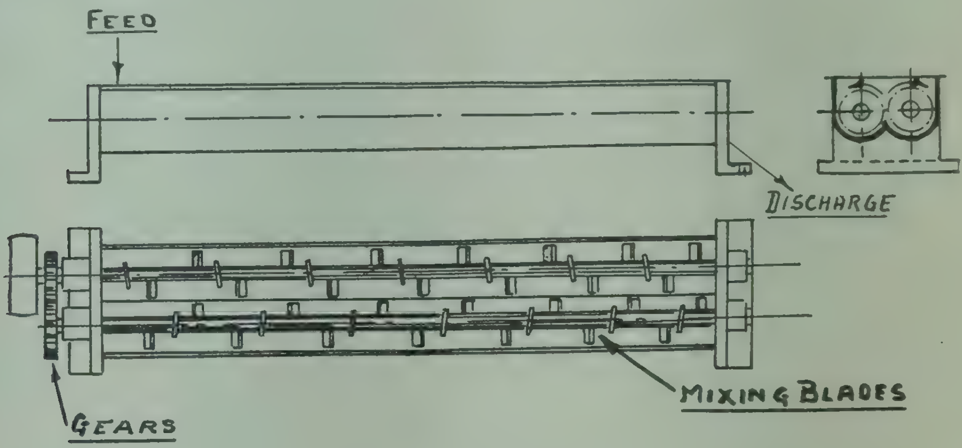


Fig. 120 Duplex Worm

Automatic bulk weighers in sets with electrical interlocking, lend themselves very well to accurate proportioning. The expense involved in installing up to perhaps eighteen weighers is, of course, appreciable. Each of the weighers will be set to cut

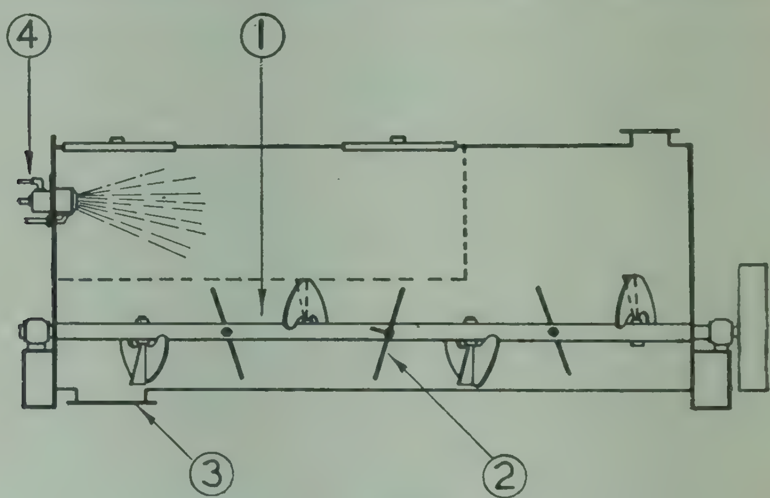


Fig. 121 Cascade Mixer

off the feed at some predetermined figure and to hold its weighment until the weighers have each received their proper weighment, when all the weighers will discharge at once. If the feed to any one of the weighers fails, the whole of the weighment will be held until the feed recommences. Light signalling or bell signalling is usually adopted to give notice of faults of this kind. Proportioning weighers of this kind usually feed continuous mixing plant, and in order that the various materials shall each reach the mixer feed point together, the length of the

paths from all the weighers to the mixer should be equal, otherwise consecutive feeding will occur and this condition is not suitable for the highest standard of mixing with continuous plant.

CHAPTER X.

CUBING

When compared with loose meals, compound cubes are more convenient and cleaner to handle, more economical in use, have better keeping qualities, and ensure the livestock consuming a balanced diet. These advantages make it worth while going to some trouble to consolidate the loose meal into cube form. The cubing is achieved by the application of pressure on the loose meal, which is usually prepared for the cubing operation by cooking, and the addition of a binding agent.

Cubes can be made without preparing the meal by cooking or adding a binding agent, but the operation is usually not so satisfactory, as it results in very heavy loads on the cubing machinery. All cubing machines to-day operate upon the continuous principle as opposed to the batch operation of the early hydraulic presses. The use of continuously operating machines is dictated by consideration of working cost and not quality of product. Quality in this sense does not refer to feeding quality, but rather to appearance and friability. The biggest difference between batch produced cubes and continuously extruded cubes is that press cubes are produced by compressing the meal on all sides, whereas in the extruded cube, two of the faces of the cube are formed by the cutting action of a knife. The two cut faces lack the finish of the pressed surfaces, and their roughness allows them to be rubbed into meal more easily than are the smooth surfaces.

An attempt to produce the finish of the press cube at the lower working cost of continuously extruded cube was possibly the reason for the design of the continuous moulding machine, in which cubes, enclosed on all sides by the mould surfaces, are produced in a continuous stream.

In all extrusion machines the meal is pressed into cubes by being forced through holes in a die plate or die ring. The use of a perforated die plate or die ring is common to all extrusion machines, but the method of forcing the meal through the die is subject to wide variation. In spite of claims which are made by the different machine makers and users from time to time, it is doubtful if any significant difference is present in the firmness of cubes produced by different machines, each running under its most suitable conditions. That there are differences is undeniable, but good samples of cubes made by the poorest

machines in this respect, are sufficiently firm for their purpose, so that the performances of machines are usually compared in terms of output, versatility, power consumption, wear and tear, accessibility and reliability, all of which are functions of working costs and not of cube quality. A cube having a pleasing finish will no doubt continue to attract the eye of the farmer, and so the appearance of cubes must be considered by the miller even if it does not put an ounce more milk into the pail.

The size of cubes is, however, a factor of real importance, as may be instanced, say, in the case of baby chick pellets where pellets exceeding some maximum size could not be fed to young chickens or, again, with rationed supplies, a smaller cube may lend itself to the more critical allocation of food supplies to each animal.

The size of cube being manufactured is normally outside the control of the man in the mill and, therefore, need not be dwelt upon, except perhaps to say that the most popular range of sizes expressed in terms of cylindrical cubes or pellets are :

3/32 inch diameter for baby chicks.
⅛ inch diameter for older chickens.
3/16 inch diameter for fully grown poultry.
5/16 inch and ⅜ inch diameter lambs and sheep and calf nuts.
½ inch diameter small size cattle cubes.
⅝ inch and ¾ inch diameter medium size cattle cubes.

It should be noted that cubes of ⅝ inch diameter and ¾ inch diameter are called medium cubes because in the early days of cube feeding, much larger cubes were manufactured, but the larger sizes have now fallen into disuse.

The length of extruded cubes varies tremendously, even with cubes being punched simultaneously by one machine, and is influenced by factors like the regularity of feed, the consistency of the meal, the thickness of the die plate and, with some types of machines, the number of knives fitted. Generally speaking, however, the length of a cube at a minimum is usually not less than its diameter, and at a maximum not more than twice its diameter, although in any bag of cubes, part cubes may be found which are considerably shorter than their diameter, but cubes longer than two diameters stand a chance of being broken into two before reaching the farm livestock.

Excessive length in a cube of the larger sizes, whilst undesirable, is not so dangerous as excessive length with poultry feeding pellets, where over long baby chick pellets might prove fatal to young chickens. Most cubes are made from meal to which molasses has been added, and this meal is subjected to some heat treatment before being fed to the cubing machine. The quantity of molasses which can be incorporated in a meal intended for cubing, may be considered to be a maximum when it reaches about 15 per cent. of the weight of the mixing, and

the probability is that most machines will not handle meals containing more than 10 to 12 per cent. of molasses. This assumes, of course, that it is desired to incorporate as much molasses as possible in the cube.

The molasses which is normally used as a binding agent for cubes is a thick, viscous liquid known as "blackstrap" and which contains 50 per cent. of sugar. Its viscosity is a hindrance to its manipulation and, therefore, it is usual to handle it in a warm condition. Students will be aware that the viscosity (or reluctance to flow) of most fluids is reduced with an increase in temperature. Molasses store tanks are usually located at or below ground level, which is convenient for receiving from transport vehicles. These tanks will normally be maintained at an equable temperature, and molasses required for manufacture will be drawn off by pumps which lift it to the level of the processing plant.

The temperature of the molasses in the main tanks is not usually as high as that considered desirable for the molasses absorption operation, and further heating is, therefore, necessary.

The final heating of the molasses may be carried out in a batch tank capable of holding a quantity of molasses sufficient for a day's working, and it is a great convenience to have this tank located at such a height that the flow to the cubing plant is gravitational. In this batch or pilot tank, heat is supplied by both closed steam and open steam. Where open steam is used for molasses heating, there should be, prior to the cubing machine, means of controlling the moisture content of the molassed meal which may involve some drying. For the guidance of students, it should be pointed out that this is the author's opinion and that it may readily be disagreed with by other authorities.

In most plants the molasses is introduced to the meal in finely divided streams, but there is a modern trend towards the use of an atomized spray. The stream of molasses may meet the meal in any of the mixers, which have previously been mentioned as suitable for this purpose, but the majority of cubing machines are served by steam heated kettles and such kettles lend themselves very readily to the intermixing of meal and molasses. The chief purpose of the kettle is to heat the meal and, if necessary, to permit the meal's moisture content to be altered, but it should also be remembered that some mixing can be achieved in a kettle having a centre shaft fitted with suitable stirring arms.

A kettle may consist of a single compartment or may be divided into two or more separate compartments. Each compartment may be steam jacketted on the sides and bottom and be fitted with perforated pipes projecting into the meal

space for the introduction of live (or wet) steam. On the other hand, individual kettle compartments may have only live steam pipes whilst others may only be jacketted on the bottom and not on the sides. The kettle allowing the greatest control over the condition of the meal is that having sides steam jacketted, bottom steam jacketted and live steam or moisture pipes fitted, all independently controlled. That such close control over the meal conditions may be an unnecessary refinement is suggested by the fact that at least one successful cubing machine dispenses with the use of a kettle altogether, and for the cooking of the meal relies entirely upon the use of a short, broken flight worm conveyor into which open steam is sprayed.

Having got a perfectly proportioned, properly mixed meal into the kettle, together with molasses, the cooking operation commences.

Many different opinions are held about the method and extent of cooking required by meals preparatory to cubing. Each opinion holder, when faced with contradiction, invariably falls back on his last line of defence which is "that years of cubing experience in his particular mill lie behind his opinion." Young students, when faced with contradictory views, each backed by "years of experience," may be forgiven some confusion, particularly in view of the fact that all the opinions expressed are almost certain to contain something of value. The facts of cooking do not as yet appear to have been clearly delineated, but students may receive some guidance from the following :

Cold meal fed to a cubing machine will become warm during the cubing operation. This heat will have been produced by friction and pressure. This heat, produced by the consolidation of the meal by compression, is unavoidable and its presence must be recognized, for under certain conditions this heat, added to the heat the meal may have been given in the cooking stage, will be sufficient to produce burnt or scorched cubes. This scorching hardly ever occurs with the larger sizes of cubes, but $\frac{3}{32}$ in. diam. baby chick pellets may be readily "burnt" in this manner. It is a demonstrable fact that cubes can be made more easily from warm meal than from cold meal, but the amount of pre-cooking necessary for best results with some machines is greater than with others.

Cooking, however, usually involves more than heating the meal, for the cooking vessel is a convenient place at which to modify the moisture content (and this usually means an increase) of the meal being fed to the cubing machine. An increase in moisture content is usually achieved by the use of live steam; in the case of kettles, through a perforated steam pipe, and in the cascade type cooker, through a series of jets.

It must be appreciated that the moisture absorbed by the meal in this way will act as a vehicle for the transfer of heat from the steam to the meal and the meal will become much hotter more quickly than would be the case if only closed steam jackets were used. Open steam cooking is, therefore, a shorter process than dry heat cooking, but the use of open steam also increases the moisture content of the meal, and where only open steam cooking is available, two undesirable positions may arise. Firstly, where the cubing operation requires the meal to be at a high temperature, the use of open steam to achieve this temperature may increase the moisture content of the meal beyond the point where satisfactory cubing can be performed and in fact excess moisture may stop the operation of the cubing machine altogether.

Secondly, where there is considerable friction heat produced in the cubing machine as, for instance, in the production of baby chick pellets, any necessary increase in the moisture of the meal can only be achieved with an accompanying overheating of the meal which again may stop the production of pellets.

With a two-stage cooking system employing steam jacketted vessels and open steam moisture pipes, the case where high temperature meal is required can be met by the use of jacket steam and open steam in the first stage, and if the meal should become too moist, the excess could be removed by the jacket steam heat of the second stage. In the case of moisture being required without excessive heating, the provision of a cold water spray may have possibilities.

A comprehensive statement of the actual effects of heat upon the meal being cubed is difficult to formulate at the present state of our knowledge, but in the oil seed crushing process, the seed meal is cooked for three reasons, namely, to coagulate the albumen, to reduce the viscosity of the oil, and to rupture the oil cells and, whilst the temperatures of compound meals are not usually as high as oil seed meals, it seems reasonable to assume that the last two effects of the oil seed cooking will occur in the compound meal, if to a lesser extent.

Both oil and moisture act as lubricants to the meal passing through the holes of the die. If oil or moisture is present in excessive quantities, either of them will stop the production of cubes by reducing the rigidity of the meal below the point where it will transmit the compressive force to the meal inside the die holes. The rigidity of the meal is probably an expression of the friction between the particles of the meal which would naturally be reduced in the presence of an excess of lubricant.

This, however, is not the whole story, for note must be taken of the gelatinizing effect of moisture and heat which will cause a reduction in mechanical stability of the particles of some of the constituent materials of the meal. The mechanical effects of

excess moisture in a cubing machine may perhaps be illustrated by considering a layer of meal lying between two horizontal compression faces, one of which is perforated after the manner of a cubing machine die plate. Consider the holes in the perforated plate to be full of compressed meal as obtains in a cubing machine during the actual production of cubes. The meal contained between the compression faces is free to flow both through the perforated plate and out between the plates at right angles to the direction of the compression force.

The resistance to the meal passing through the holes in the die plate is determined by the frictional resistance between the meal and the comparatively smooth surface inside the holes. The resistance to the meal flowing out from between the compression faces is determined by the friction of the meal, partly on itself, and partly on the more broken surfaces of the compression faces. An excess of moisture reduces this latter resistance to a point where it is less than the resistance of the dryer meal already in the die holes, and thus allows the meal to pass out between the faces. On the other hand, some moisture will assist the passage of the meal through the die holes, provided that when the moisture is approaching the critical limit, the moist meal is not fed immediately after dry meal.

When a die plate is not punching properly, it is often possible to clear it by feeding it with a few shovelsful of cubes which, having been once compressed, present a much more rigid meal to convey the compression force on to the meal blocking the die holes. Rigidity is then a factor which has a very important bearing on the cubing characteristics of a meal, and this characteristic of the meal is influenced to a critical extent by the cooking operation.

Consistency of cooking will avoid variation in meal rigidity and thus obviate the position arising where damp meal between the compression faces is trying to displace comparatively dry meal in the die holes.

As well as different degrees of cooking being required for different cubing machines, different mixings worked on the same machine may call for quite different treatment in the cooking stage. All cubes tend to swell slightly as they leave the knife side of the die plate, and with some mixings, excessive heat or moisture encourages this swelling to a point where surface splits develop down the length of the cube and, in some instances, these cracks may penetrate almost to the centre of the cube, thus ruining the appearance of the cubes as well as making them more easily disintegrated.

Cooking faults can only be detected once the meal has reached the die plate, or at least left the cooking vessel, when it is too late to remedy that particular sample of meal. There

will be a time lag before adjustments made to the cooking control have time to operate, and during this time, improperly cooked meal will be reaching the cubing machine unless a bypass is available between the cooker and the cubing machine. The effect of this time lag will be exaggerated if the cooking vessel is of large capacity, and this seems to be one reason for having comparatively small quantities of meal in the cooking stage at any one time. At the present time, the control of the finer points of cooking is completely dependent upon the skill and experience of the operative who, when working upon a machine and with a mixing to which he is used, has probably no equal. It is only by working as a cubing machine operative that the full significance of cooking conditions can be realized, which is not quite the same thing as saying that every cubing machine operator does possess this understanding.

It seems proper to consider cubing machine operation from the point where a new machine is being put into service for the first time. A cubing machine, like most other machines, needs a " running in " period, during which the machine will not be stressed to its full working capacity. Apart from the wisdom of not subjecting the machine parts to heavy loads in the first hours of their working life, careful treatment of the die when first used will be well rewarded. In fact, some machines, particularly earlier models, would refuse to punch cubes satisfactorily until the running in period was complete.

The only part of the running in process which students need consider in any detail is that appertaining to the surfaces in contact with the meal, for proper treatment here will automatically ensure proper treatment of bearings and mechanical transmission generally. Running in the die is usually interpreted as supplying the machine with a smooth meal at a moderate rate, but in certain circumstances with some machines, once-pressed cubes have to be fed to the machine to take the roughness off the die holes.

Nowadays, most dies have holes machined to a really smooth finish and this has considerably reduced the waiting period before the machine can be said to be working at full capacity. To-day, it is possible to feed a new machine right from the start with a standard mixing and produce perfect cubes from a high percentage of the holes. Such practice is not, however, recommended. The higher the initial polish (which is helped by gentle working) that can be achieved on the faces over which the meal passes, the longer will be the life of the die and the greater will be the output per horse power of the machine.

Under normal conditions to-day, most new machines should be run for a period up to, say, one hour with an oily meal and then for its first production job be fed with one of the " easier " mixings. One example of an easier mixing in this sense would

be a mixing containing a fairly large proportion of ground nut cake meal. The oily meal referred to above is not a normal mixing which happens to have a high oil content, but to any suitable absorbing meal to which has been added, say, 10 per cent. of oil, and which, after passing through the machine, is retained for further use. Such a meal, apart from the use just described for it, will be used at the end of every working period to fill up the die to provide a meal which can be punched out of the die fairly easily by the normal feed at the commencement of the next working period. The usual frequency of such treatment is daily, but at any time that a machine is stopped and not expected to be re-started within a couple of hours with large cubes, down to, say, half-an-hour with the smallest pellets, the die plate should be filled with an oily meal before the machine is stopped.

When a machine stops due to mechanical breakdown or other unforseeable circumstances, the use of oily meal is not, of course, possible, and in such circumstances liquid oil poured on the meal in the die is a good second best, provided the design of the machine makes such action practicable.

With the dies for the larger sizes of cubes, steel is the most common metal from which they are made, but for smaller cubes and particularly for pellets, bronze dies with their lower coefficient of friction are almost essential for satisfactory working.

The knives used to cut off the cubes do so not directly in terms of a fixed length of cube, but in terms of the length of a cube that is extruded through the die per revolution of the machine, so that the length of cube is not influenced by the knife action. The exception to this is found in machines which may be fitted with more than one knife as, for instance, the Californian Press and the Pelcub machines, and here, one, two or four knives may be fitted. The number of knives fitted fixes the length of cube to the length that is extruded in one rev., one half rev., or one quarter rev., depending upon whether one, two, or four knives are used. The multiple knife feature of these machines makes a valuable contribution to their flexibility and allows the highest possible production where the cubes have to be made short in length or where they are being made from a mixing which flows comparatively easily through the die. In the absence of this multiple knife feature, the length of cube with an easy mixing can only be controlled by reducing the feed with a consequent drop in production. The actual parting off of the cubes may vary from pure cutting to mere breaking, and whilst the condition of the knife edge is of importance, the effect of the relative velocity between the knife and the cube should be borne in mind. The speed of the machine is, however, a factor

which is largely determined by the makers and need not therefore be further considered at this stage.

CUBE MOULDING MACHINES.

These machines operate upon a principle which is, at the present time, the only alternative to the extrusion principle. Moulding involves the forming of the cube by complete closure under pressure, as a result of which cubes from any one moulding machine are all the same size in contrast with the product from extrusion machines.

The preparation of meal for the moulding operation is very similar to that for the extrusion machine, but generally a much higher cooking temperature is worked to and a higher percentage of molasses may be contained in the meal, averaging about 16 per cent. One advantage which the moulding principle has, apart from any advantages its products may have, is that at no point is the meal used to transmit pressure, so that merely from the point of view of pressing there is a greater latitude in the condition of the cooked meal, hence its ability to hold a greater quantity of molasses. The great weakness of the moulding principle, again apart from any weakness its products may have, is the short duration of the applied pressure on any one cube. The only class of continuous moulding machine used is that which makes use of two cylinders revolving against each other, face on, with the cylinder faces suitably toothed or pocketed to contain the meal fed between them.

In order to increase the pressing time and reduce the slipping back of the feed, the cylinder diameters are made as large as is practicable. Each of these cylinders constitute half dies, and both have to be changed in order to change from the manufacture of one size of cube to the manufacture of another size.

The size of the dies means that they are heavy and not very conveniently handled, so that changing the dies involves considerable waste of time and for this reason individual machines are usually reserved for one particular size of cube, other sizes being made by separate machines.

In the past few lessons, the general principles underlying the preparation of meal for, and its compression into compound cubes has been considered. In the following, reference is made to several representative machines in which these principles find practical expression. Fig. 122 shows a part sectional view of the Californian Press, manufactured in England by Messrs. Henry Simon Ltd. As will be seen from the diagram, the Californian Press is an edge runner type of machine. One striking difference between the machine and most other machines is the use of a worm trough type of cooker (4). In the diagram, the cooker shaft is shown fitted with angle shaped lifters (5),

but the writer understands that crescent type blades are now fitted. The cooker is fed by the variable speed worm (1), which is operated by a pawl and sprocket mechanism (3) from a crank (2) fitted to the end of the cooker shaft which, in its turn, is driven by a chain drive (7) from the main gear box (15) through bevel gears (6). The cooked meal conveyed through the cooker by the progressing action of the lifters is fed into the bowl (8) through the chute (9). The bottom of the bowl (8) is formed by the dieplate (13), upon which run four rollers (12) carried in a casting called a " spider " (11), which is fastened to the shaft (10).

The meal is compressed into the die holes by the revolving rollers and emerges from the underside of the die plate as cubes

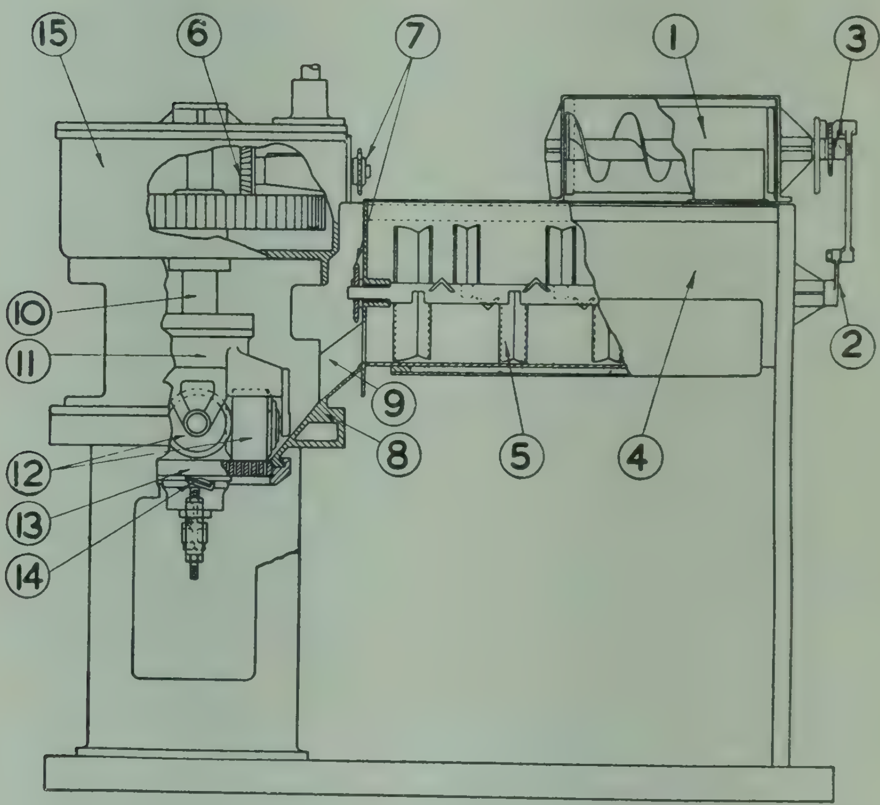


Fig. 122 Californian Press

which are cut off by the revolving knives (14). The machine is normally driven by an electric motor (mounted on the far side of the machine in the illustration) through a " Vee " rope drive, the driven pulley of which is fitted to the shaft (shown broken in the diagram) which projects from the bearing on the top of the gear box.

The details of the machine shown in the diagram are not

necessarily the maker's latest practice; for instance, the knife (14) is no longer of the pattern shown, but is a bevelled edge circular knife which is free to revolve upon its own axis, as well as revolving as a whole about the main axis of the machine. Again, the cooker is not now made steam jacketted. However, the essential principles of the machine remain unchanged, and the following points should be noted.

Whilst the machine is working, the feed may be altered by an easily made adjustment to the pawl travel, and a graduated scale allows previous settings to be repeated. The meal enters the bowl at one point only. The die plate is stationary and is removed from the machine by passing downwards over the tail of the mainshaft after the knife gear and the split die-clamping ring have been removed. The compression rollers are fluted, the flutes having a slight slope across the face of the roller. In front of the rollers, in the direction of rotation, are fitted adjustable ploughs to guide the meal into the path of the rollers,

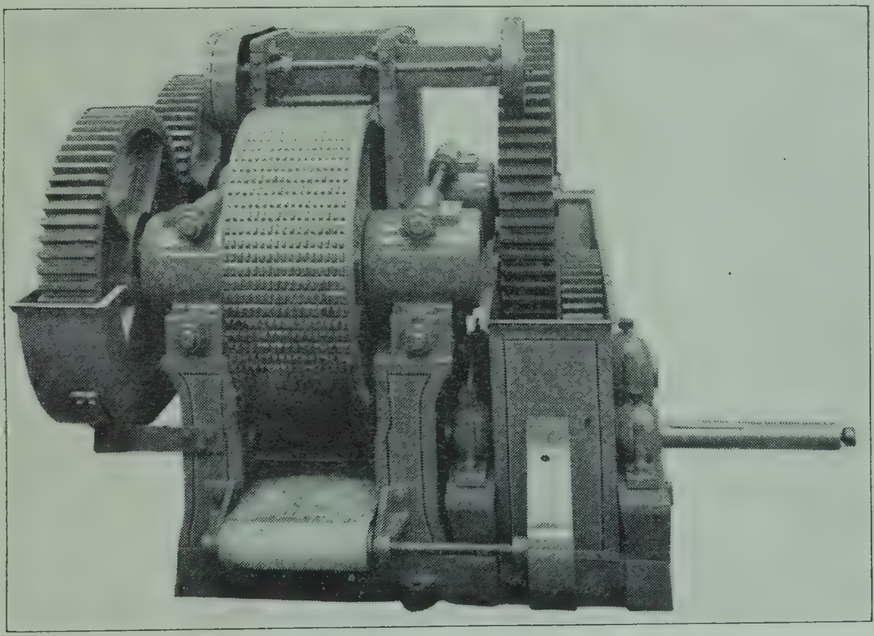


Fig. 123 The Marshall Moulding Machine

and keep the bowl surfaces clean. The vertical shaft revolves at about 50 r.p.m. and the machine may be fitted with either a 30 h.p. or a 40 h.p. motor.

Control of cooking is helped by a dial thermometer, the bulb of which may be located in the end of the cooking worm or at the beginning of the feed chute. For the addition of molasses to the meal, the Simon atomizer equipment may be fitted instead of the ordinary cooking worm, and in this case the cooker and atomizer may have it own driving motor.

The Marshall machine, shown in Fig. 123, represents the moulding type of machine and the form of the die wheels is clearly shown. The meal is given a preliminary packing in the feed box before falling between the die rolls. The die rolls, which revolve at about 7 r.p.m., are coupled together by a pair of gears so that they may run at the same circumferential velocity in opposite directions. A short band conveyor collects the cubes from beneath the dies and delivers them just clear of the machine. The shape of the cube produced is illustrated in Fig. 124, although other moulding machines operating on the same principle may produce other shapes of cubes by using dies having different shaped projections or recesses. The die faces are kept free of caked meal by scrapers bearing on the roll faces after the point of cube discharge. Where a machine is reserved for one particular size of cube, the dies need only be removed when wear has made re-cutting necessary.

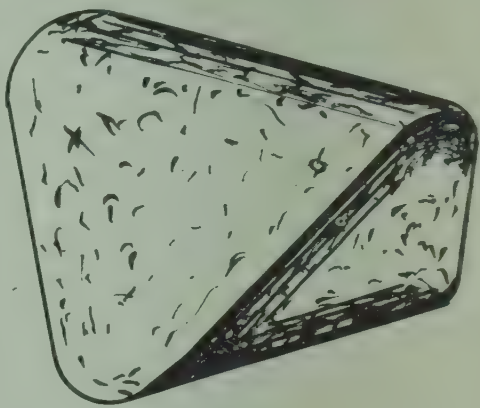


Fig. 124

Cubes from a moulding machine usually leave the machine joined together by a thin layer of meal that has been compressed between the " lands " of the dies. The " land " being that part of the die surface between the teeth or recesses. This " toffee-slab " like form has to be broken up so that each cube may be an individual unit. The breaking is usually effected by a rake in the path of the cube slab and against the teeth of which the slab breaks up. The separated cubes still have attached to them projecting pieces or wings as they are called of the compressed sheet of meal, which had previously joined the cubes together and these have to be removed before the cubes are bagged.

The Pelcub Major cubing machine, illustrated in Fig. 125, is made by Messrs. Richard Sizer of Hull, and, like the Californian Press, belongs to the " edge runner " class of machine. The illustration shows part of the casing cut away to disclose a part section of the die plate and rollers. In this machine, the rollers and knives revolve together whilst the die plate revolves in the opposite direction. The feed which enters the machine through the chute shown falls into a distributing bowl which has four adjustable ports distributing the meal over the die, whilst ploughs fastened to the roller spider guide the meal into the path of the rollers. The gear box, with the driving mechanism in this machine, is situated below the level of the die plate, which means that the die is removed by threading upwards over

the main shaft after having first removed the distributing bowl, the lower half of which carries the compression rollers. For the purpose of removing the die, the makers supply a lifting block attached to a cantilever rail hinged on to the side of the kettle. The machine is driven by a 45 h.p. motor, the kettle being independently driven.

The Sizer "Cuber," illustrated in Fig. 126, is the modern version of the original continuous cubing machine, and Fig. 89 in the first year text-book indicates the principle upon which the machine works. The die of the machine is fixed and its outer face is traversed by a knife revolving with the compression worm shaft. It is sometimes claimed that this type of machine is less critical of its treatment, and of the condition of the meal fed to it, than are many of the other bigger and more elaborate machines. Probably, there is no machine which permits a more rapid change of dies.

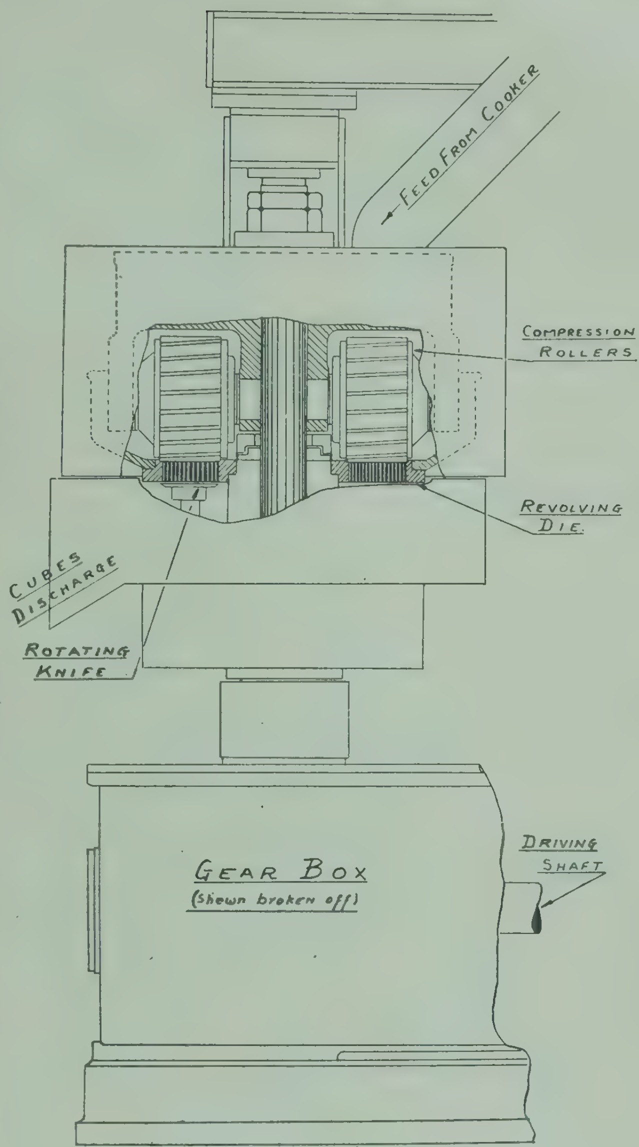


Fig. 125 Pelcub Major Cubing Machine

A further product of Messrs. Richard Sizer Ltd. is the "Orbit" machine, illustrated in Fig. 127, which should be studied in conjunction with Fig. 88 in the First Year text book. This machine makes a very firm cube, comparable with that produced by the swashplate type of machine, and which is the result of the acute compression angle. The internal compression roller and the die are each mounted on independent driving shafts which

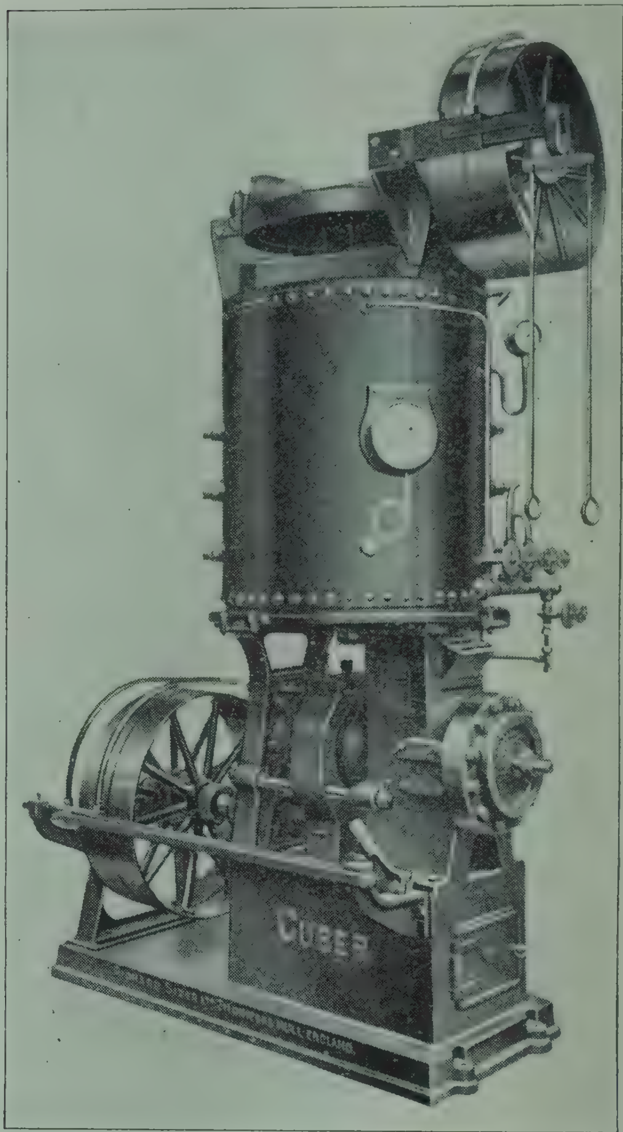


Fig. 126 Sizer "Cuber" Machine

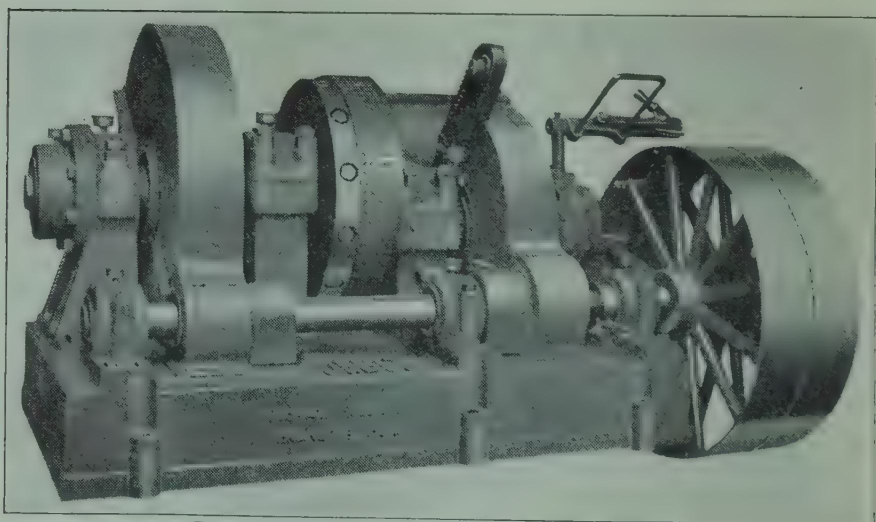


Fig127 Sizer "Orbit" Cubing Machine

are geared to a common countershaft. When removing the die, the pedestals carrying the die shaft bearings, complete with the shaft, are slid away from the compression roller until the die ring is clear of the roller, when, after removing the bolts holding the die to a flange fastened on the driving shaft, the die can be lifted clear of the machine. The reverse of this operation is carried out in refitting the new die.

The cubing machine manufactured by Messrs. George Porteus & Son Ltd. is shown in Fig. 128. Unfortunately, whilst giving a good idea of the external appearance of the machine, this does not convey a great deal of information about the working parts.

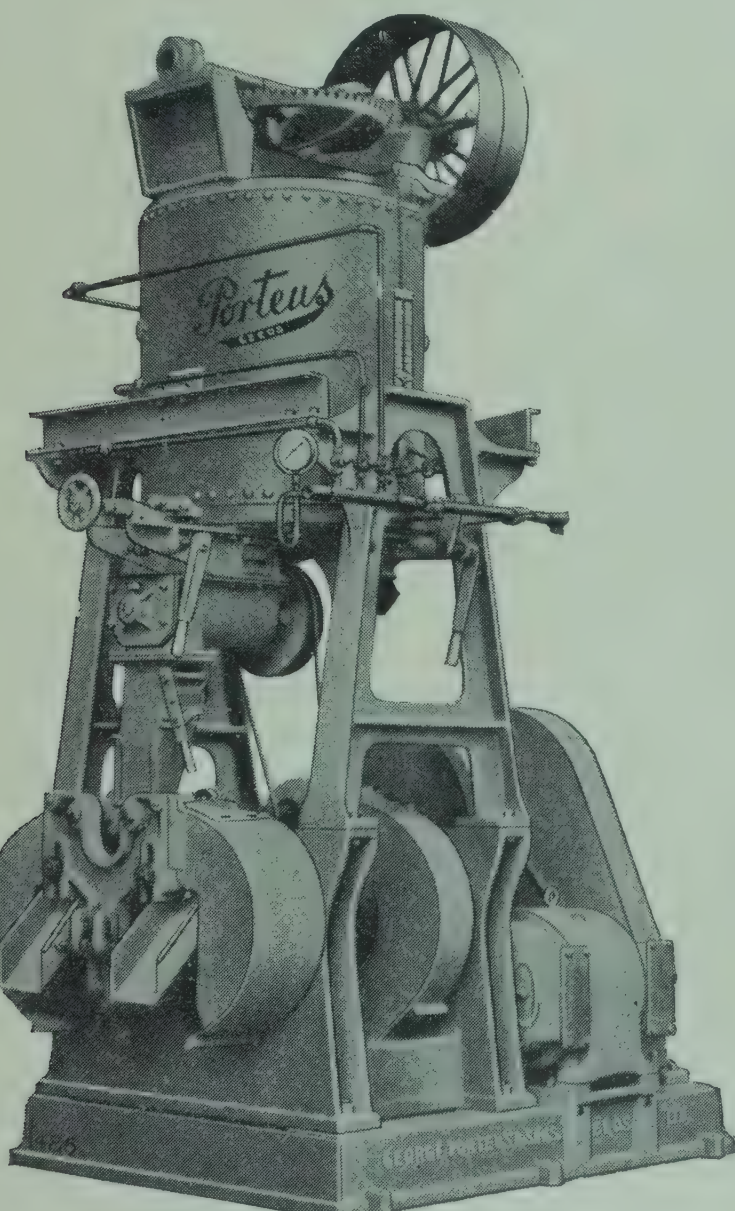


Fig. 128 Porteus Cubing Machine

Students will have learnt from a previous lesson that this machine employs a pair of mating spur gears having die holes located between the roots of the teeth and passing through the rim of the gear. This arrangement produces two separate streams of cubes which flow down the discharge chutes shown in the illustration.

CHAPTER XI.

CUBE COOLING

The keeping quality of compound cubes, as indeed of all feeding stuffs, is influenced chiefly by the conditions of the material when put into storage. The miller can exercise no control over the cubes once they have left his mill, but he can make certain that the cubes are in a proper condition when bagged up.

The cubes are responsive to atmospheric conditions, although less so than meals, and the only characteristics of the cubes which are altered by atmospheric conditions are temperature and humidity. The proper control of their temperature and humidity will endow the cubes with a maximum "storability." The optimum conditions of temperature and humidity (or moisture content) for any particular size and nature of cube does not appear to have been precisely determined and, in fact, a precise determination would probably have only an academic interest as far as the practical business of every-day feeding stuffs manufacture is concerned. It is sufficient for all practical purposes that cubes having a moisture content of not more than 12 per cent., with a temperature of not more than about 75 degs. F., when packed in jute bags, will keep satisfactorily for all normal storage periods.

When they leave the cubing machines, in almost all cases cubes have a temperature and moisture content considerably higher than the limits prescribed and they must be cooled or cooled and dried before they may be bagged safely. The cooling and drying of cubes is almost universally effected by the use of cold air currents.

In general terms, the proper function of a cooler has been stated as producing cubes at the sacking-off point in a condition most conducive to good storing qualities. This statement may now be expanded to cover the following points :

(1) The temperature of the cubes leaving the cooler shall not be higher than 75 degs. F., or some other temperature which may have been decided upon.

(2) The moisture content of the cubes shall not be greater than 12 per cent. and should be fairly equally distributed throughout the body of the cube.

(3) To avoid formation of tail ends, the cube shall not be subjected to severe handling whilst in the cooler.
(4) The cooling and drying shall not proceed at an excessive rate at any stage, so that the locking of heat and moisture in the heart of the cube may be avoided. (This sealing of heat and moisture inside the cube is caused by the formation of a high resistance surface layer by an excessive rate of surface evaporation and cooling).
(5) The quantity of material contained in the cooler at any one time shall be a minimum. (This is necessary to avoid delays at the beginning and end of the working period by the need for filling and emptying the cooler).
(6) Or alternatively, where the cooler does normally contain a large quantity of cubes, there shall be arrangements to provide for proper cooling facilities when the cooler is only partly filled.

To the above list may be added one or two other characteristics which, although not affecting the treatment of the cubes, increase the general desirability of any cube cooling apparatus.

Firstly, the air exhausted from the cooler should not be allowed to escape into the working space of the mill without first having been stripped of entrained dust. Secondly, the exhaust air, which in most cases will have a fairly high moisture content, should not be discharged where the moisture can condense on surfaces inside the mill. Failure to meet this condition will result in unpleasant dripping of water, to say nothing of the corrosion of unprotected metal or the spoiling of painted surfaces. Thirdly, a cooler should have adequate means of access to its interior to facilitate cleaning, particularly in the case of a conveyor type cooler.

This list of characteristics may be used as a basis for comparing actual cooling installations one with another, but it should be borne in mind that the characteristics so far referred to are largely concerned with the condition of the material being produced and the working conditions, and that there are a number of other points chiefly concerned with the economics of the cooling operation which it is not intended to refer to at this stage.

The rate of cooling will depend upon :

(1) The temperature difference between the surface of the cube and the cooling air.
(2) The rate of air flow.
(3) The rate of diffusion of the heat in the cube from the centre to the surface.
(4) The size of the cube.
(5) The shape of the cube.
(6) The thickness of the cube bed in the case of coolers in

which the air flows through the mass of cubes, or the shape of the cube bed in those coolers in which the air flows over the mass of cubes.

(7) The amount of drying that is taking place simultaneously with the cooling.

Of the first three factors, the limiting factor is probably the rate of heat diffusion from the centre to the outside surface of

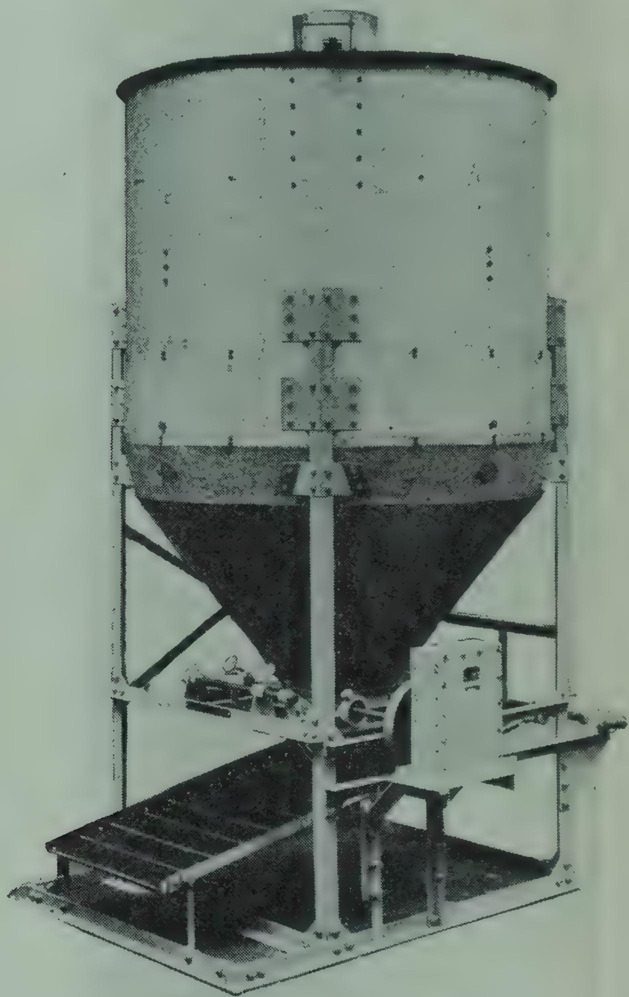


Fig. 129

each cube, and no extremes of air flow and temperature difference will push the cooling rate beyond the limit imposed by the internal diffusion of heat. When discussing the cooking of meals preparatory to cubing, the suggestion was made that the moisture introduced into the meal, by the use of live steam, acted as a vehicle for the transfer of heat. This same moisture can now be used as a vehicle for the transfer of heat from the cube and, in fact, must be so used if the cubes are to leave the cooler in a satisfactory condition.

The transfer of heat by surface evaporation as applied to cube cooling has not been thoroughly explored, but practical experience suggests that excessive surface cooling retards the diffusion of moisture from the interior of the cube, thus causing a breakdown in surface evaporation sufficiently long to allow the cubes to leave the cooler and be packed before the internal moisture again penetrates to the surface of the cube. When this

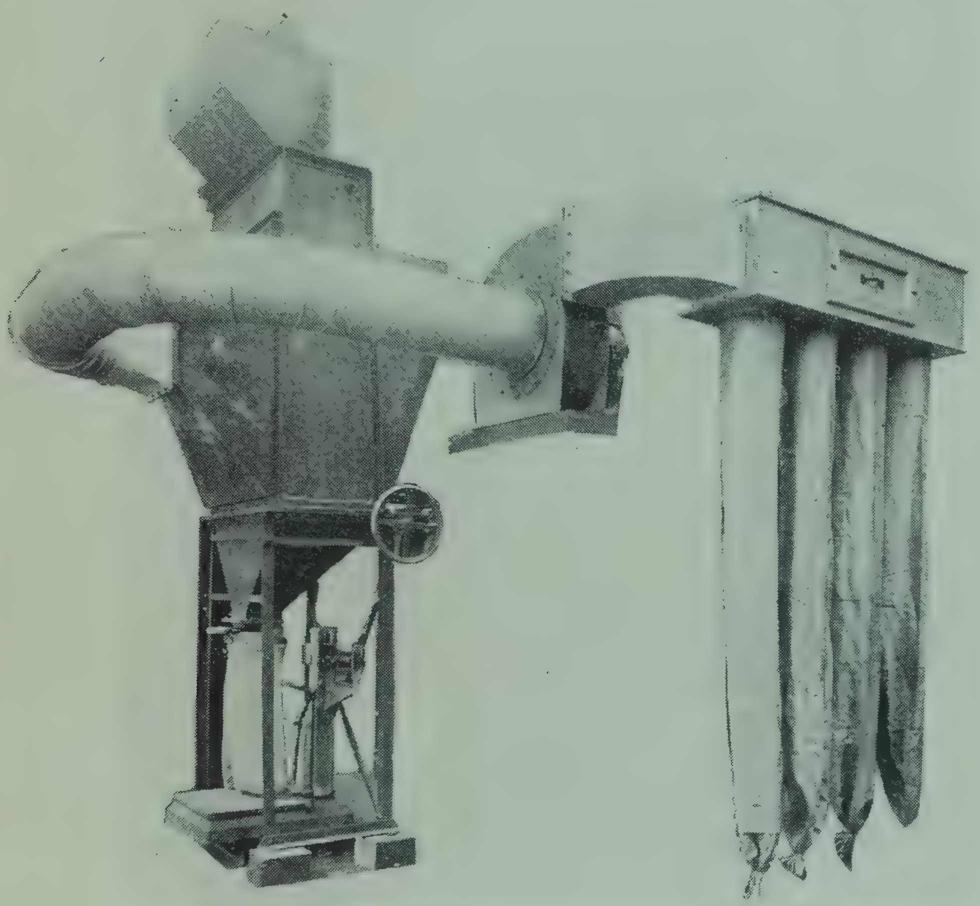


Fig. 130

happens, the moisture which reaches the surface of the cube in the bag, being no longer in the path of an absorbing current of air, remains on the cubes to give rise to the phenomena of sweating and mould growth, which are fatal to the millers' reputation should they be undiscovered until the cubes have reached the farmer.

The effect of the size and shape of the cube upon the drying rate is most obviously seen when expressed in terms of surface area per cubic content, that is to say, the cube having the greatest surface area for any given volume should cool the quickest if all other conditions are constant; students may note that a spheric-

ally shaped cube would be the worst in this respect, a sphere being the shape which presents the least surface area for any given volume. If cubes were all handled independently in the cooler, no more would have to be said about the effect of shape, but as they are treated in masses, the accessibility of the inner cubes of the mass to the ventilating air must be taken into account. The accessibility of the cubes will be a function of the porosity of the cube mass, which is another way of expressing the packing together of the cubes in the mass.

Now, the packing of the cubes in a mass will clearly be influenced by the shape of the cubes, and in this respect the sphere has the advantage, for a sphere's contact with its neighbours must be limited to a mere point of surface per contacting cube. A cylindrical cube may make line contact along its length and area contact at each end, whilst a square cube may make area contact on all its faces. In the absence of experimental data it is not possible to say to what extent good accessibility counteracts minimum surface area per unit volume and *vice versa,* but students will see that the effect of cube shape on the cooling rate is not nearly so obvious as it might appear at first glance.

In the First Year text book a distinction was drawn between those coolers through which the cubes flow by gravity and those coolers through which the cubes are conveyed by mechanical power, and the relative merits and demerits of these types may now be considered.

Conveyor Type Coolers

These may be split up into two groups, one in which the cooling air passes over the face of the cube stream, and the other in which the air passes through the cube stream. The case where the air passes through the stream of cubes lends itself to the most effective cooling, viewed merely as a temperature reducing operation, but to allow the air to flow through the conveyor the supporting band must be perforated and this is usually achieved by using a wire mesh band. Such wire bands lend themselves to the attrition of the cubes, are not particularly robust, and create air sealing difficulties at the edges of the band in the type of conveyor in which the air does not flow through the cubes once only, but is constrained to follow a tortuous path (see Fig. 95 in the first year text book).

A further limitation of the perforated band type cooler shows up where the feed to the cooler is interrupted for a while, leaving a length of the conveyor band uncovered and thus providing a low resistance path for the air which naturally takes immediate advantage of it, thus robbing the cubes of the air needed to cool them. The conveyor cooler, in which the air flows over the

surface cubes of a bed of cubes being carried on a solid conveyor band, is largely free of the disadvantages of the wire mesh band, but the need for presenting as many cubes as possible to the direct action of the air stream involves the turning over of the cube bed at intermediate points in its journey through the cooler. The turning over is usually effected by constructing the cooler in the form of two or three superimposed conveyor bands, the discharge from one being the feed to the band immediately below (Fig. 96 first year text book). This cooler, from many points of view, is a very satisfactory apparatus, and the moving bands travel so slowly, about five feet per minute, that wear of moving parts is not excessive. Conveyor coolers generally do not carry large quantities of cubes at any one time, so that there is no more than a five or six minute lag between the starting up of the cubing machine and the sacking off of cubes from the cooler. Conveyor coolers operate with about four to five thousand cubic feet of air per minute for about four tons per hour of cubes cooled, although it will be clear that the condition of the air used for cooling and the design of the cooler may modify this figure.

One feature of conveyor coolers which should not be overlooked is that they do not normally occupy floor space, being installed above man height and so leaving the floor free for storage or other use.

Gravity Flow Coolers

This type of cooler has become more popular than the conveyor type with considerable justification, but most of the conical versions still possess the disadvantage of requiring the cooler to be full of cubes for satisfactory cooling and, as a number of these coolers hold anything up to four or five tons of cubes, the delay occasioned at the beginning and end of a working spell must be reckoned with. On the other hand, the capacity of the cooler means that when full the cubes being fed are in the cooler for a period of approximately one hour, if the rate of feed is in the region of four or five tons per hour.

Large gravity flow coolers, apart from the time lag due to filling, are often inconveniently large to install in existing plant layouts without incurring extra handling of the cubes in elevators and conveyors. Handling of cubes between the cubing machine and the cooler should be kept at a minimum to avoid the formation of tail ends. In view of these disadvantages, there is a marked tendency for machinery manufacturers to reduce the size of gravity flow coolers, but unless the cooling rate is increased to compensate for the loss of cooling time, the cooling capacity must necessarily be reduced.

A typical conical cooler is illustrated in Fig. 129, which shows

a product of Messrs. Henry Simon Ltd., and a sectional sketch of which appears in Fig. 92 in the First Year text book.

A gravity flow conveyor which departs from the popular conical pattern is the Flare cooler of Messrs. Richard Sizer Ltd., illustrated in Fig. 130. The makers claim that the Flare cooler operates satisfactorily whether completely full or only partially filled. (Students should refer to page 158 of the first year text book for an explanation of the operation of this cooler).

CHAPTER XII.

WEIGHING AND PACKING

After cooling and sieving, cubes are bagged up in quantities convenient for handling and selling. Quantities of 112 lb. and 140 lb. are normally bagged, the 112 lb. chiefly for poultry pellets.

The majority of millers probably use the simple bag spout for sack filling. The spout is usually part of a small storage bin or is surmounted by such a bin. The spout itself may be of mild steel sheet or of cast iron, but in most cases the spout mouthpiece to which the bag is attached is formed of an iron casting (Fig. 131). The most common method of holding the bag on the spout for the filling operation is by a leather strap which is fastened to the spout mouthpiece and which is fitted with a quick release buckle.

In view of the fact that two hands are required to fasten this type of sack grip at the same time as the bag is being held in position, its convenience is not as good as could be required, and for really fast work with an average operator, the one hand operated toggle action grip offers advantages. The toggle action grip (Fig. 132) consists of two rigid jaws hinged to a toggle lever on the side of the spout farthest from the operator and which move away from the spout by a one-hand operated lever and close upon the sack by a reverse movement, thus leaving the other hand free to hold the sack in position.

A novel type of sack grip, although not likely to be found in the Compound mill, consists of a collapsible tube which forms the lower end of the bag spout and which is connected to a supply of compressed air. The empty sack is placed over the tube when it is deflated and the movement of a three-way valve admits air to the tube which is immediately inflated, gripping the sack from the inside to make a dust-tight joint. When the sack is filled, the air is released by a second movement of the three-way valve and the full sack drops clear of the spout. A sack to contain cubes should be big enough to hold its proper quota without possing, but cubes being packed almost invariably receive some possing from the knee of the operator or from the step of a sack

truck; such practices should be used with discretion to avoid the crumbling of the cubes. As an incidental result of knee possing, it is necessary when erecting sacking-off spouts to ensure the spout is really rigidly fixed to the supporting or

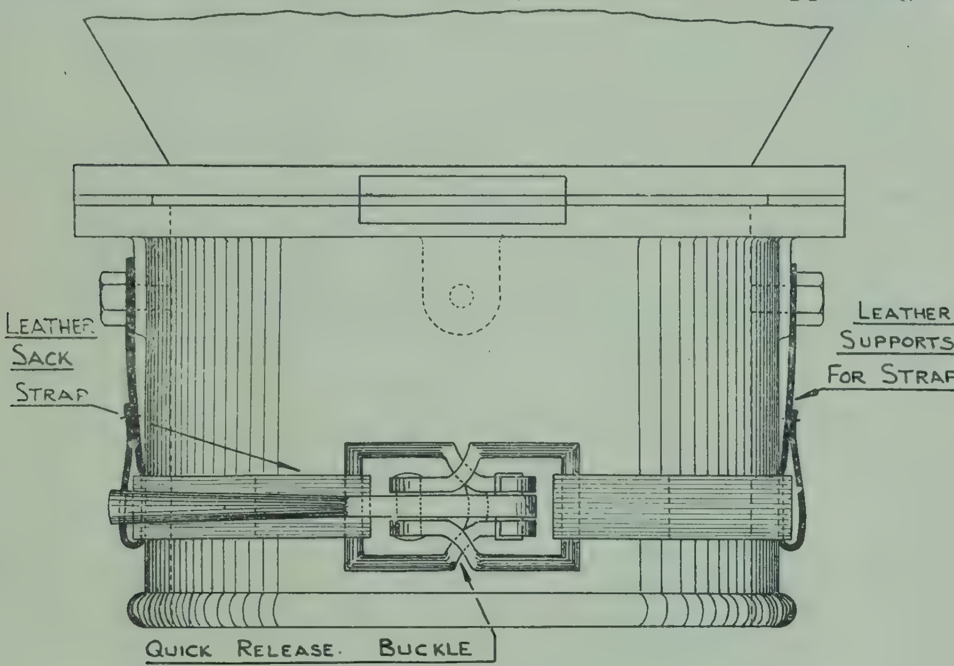


Fig. 131

adjacent structure, for any slight unsteadiness will be quickly taken advantage of by the swinging bag of cubes and the failure of the spout and/or supporting structure may easily ensue.

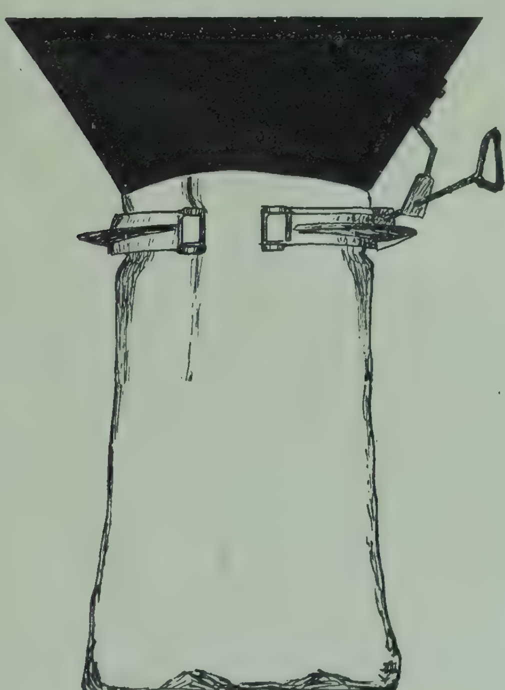


Fig. 132

It may not be out of place to consider for a few moments the valve by which the flow of cubes into the bag is controlled. In most cases this will be a simple push-pull slide, and as the operator will usually spend at least eight hours more or less continually operating the slide, its ease of operation will clearly be of importance to him. The hand grip of many slides leaves much to be desired and probably the best form of grip is that illustrated in Fig. 133a, which seems to have a number of advan-

tages over the grip illustrated in Fig. 133b. Some slides are attached to a lever or a system of levers in such a manner that the operator enjoys a mechanical advantage. The great bugbear with many slides is that occasioned by meal depositing itself in the slide tracks and frequently jamming the slide, thus needing a disproportionate effort to close the slide. Many slides fit so easily in their tracks that meal leakage ensues and little heaps of

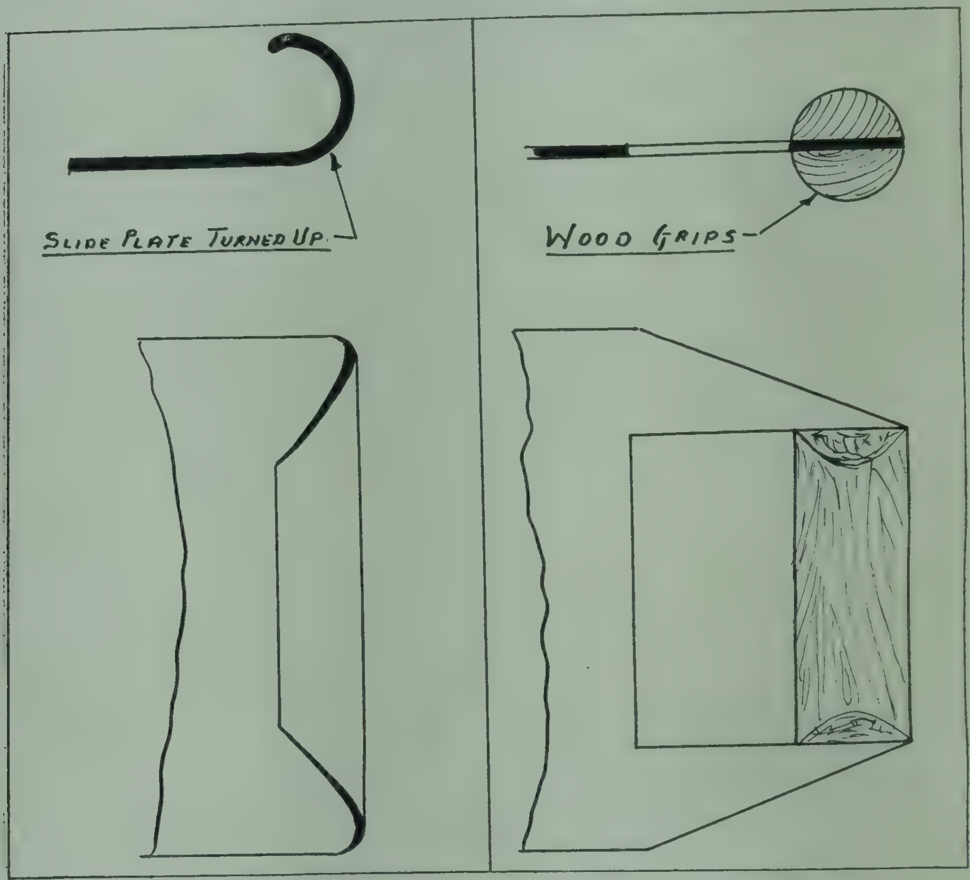


Fig. 133b Fig. 133a

meal pile up on the floor. If the sacking-off spout should be in contact with the air in the cooler into which the air is blown, then with an ill fitting slide, the operator may receive occasional blinding gusts of meal laden air. It is probably true to say that faulty slide operation can cause more unpleasant working conditions than any other plant fault of a similar magnitude.

Cubes which have been packed into bags through a simple bag spout will, of course, need weighing after the bag has been removed from the spout, and the portable platform scale is almost invariably used for this purpose. Two types of platform scale are illustrated in Figs. 134 and 135. The difference between them is that in the machine illustrated in Fig. 134, the steelyard

beam with its sliding weight is mounted on the top and is immediately accessible. Whilst necessary where a variety of weights are being checked in succession, this arrangement offers no advantages for the continual checking of a fixed predetermined weight and, in fact, its open location makes it liable to misuse. Under these latter circumstances, the machine illustrated in Fig. 135 has much to commend it. The weight measuring mechanism is completely enclosed in a chamber which may be locked, and is, therefore, protected from damage, and the move-

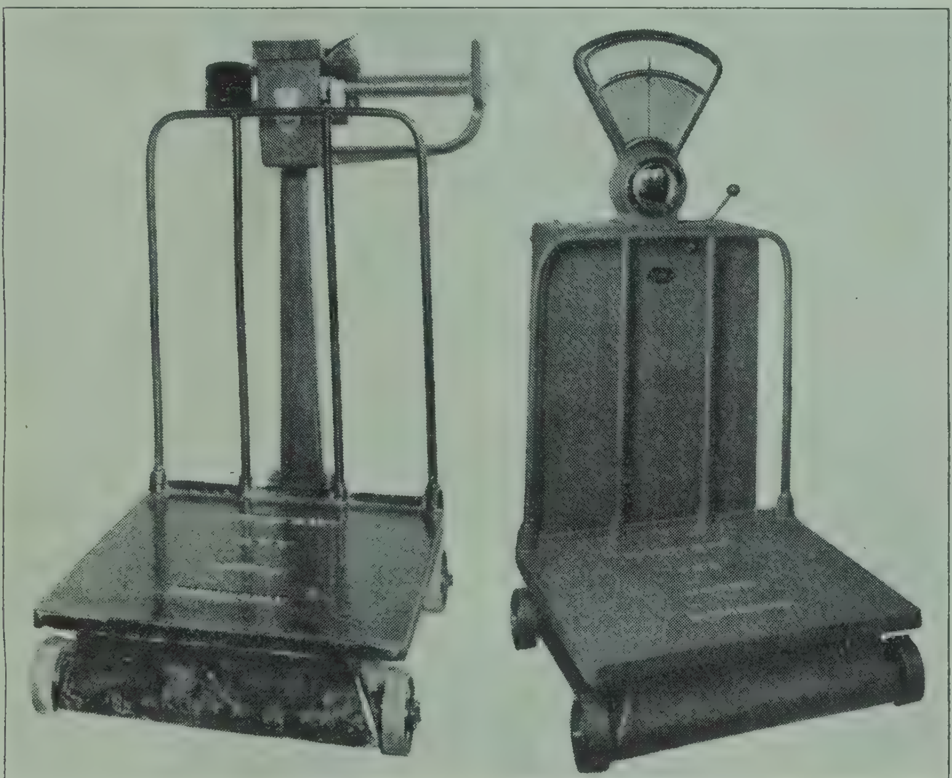


Fig. 134 Fig. 135

ment of the beam is transmitted to a pointer traversing a graduated scale mounted on top of the beam chamber. The graduated scale does not indicate actual weights but has a centre zero correct weight mark, with light and heavy weighments marked to the left and right of the zero respectively. The platform of both types of scale is supported on knife edges resting on a system of levers and is balanced against the sliding weights on the steelyard arm. In using portable platform scales, the word "portable" should be ignored as far as possible, continual movement not being conducive to long, accurate and trouble free operation, for some operatives, in moving a platform scale, treat it as though it were a bulldozer. The employment of the operative depends upon the miller making a commercial success of his business, and the despatch of wrongly weighed bags of finished

products will quickly tell against that success. If the bags are underweight, apart from contravening the law, the customer is likely to take his business elsewhere; if they are overweight, the miller is suffering a direct loss which will be reflected in his capacity to offer employment. As a matter of self-protection, weigher operatives should exercise the greatest care in their jobs and all other employees should treat weighing machines generally with the greatest respect.

WEIGHER PACKERS.

An improvement upon the separate packing and weighing of cubes is to be found in the use of weighers of the automatic and semi-automatic types. In these machines, the cubes are either

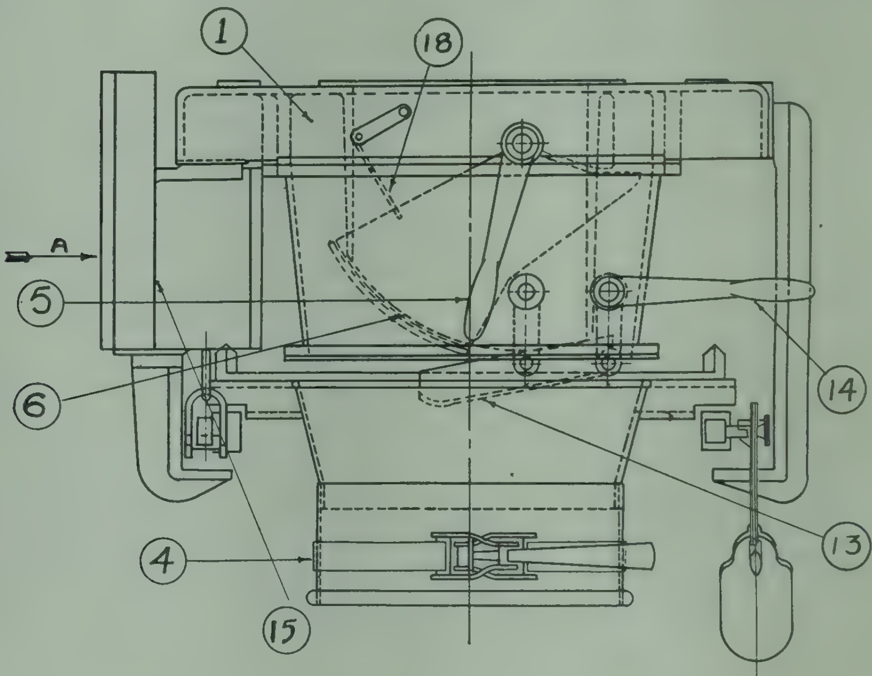


Fig. 136 Front View

weighed before they reach the bag or are weighed as they enter the bag, in both cases the bags are ready for closing as soon as they are taken off the sacking-off spout, thus avoiding the extra handling involved in the platform scale method of weighing.

As was mentioned in an earlier lesson, there are a number of machines available for the combined weighing and packing operation, and the Combined Weigher and Check Scale machine manufactured by Messrs. Richard Simon Ltd., of Nottingham, has been chosen to illustrate this lesson (Fig. 136).

It will be seen that a strong iron casting (1) supports an equal armed weigh beam (2), at one end of which is hung a

weight box (3), and to the other end is attached a freely hinged sacking-off mouthpiece (4). When the bag has been fitted on to the mouthpiece, the filling operation is commenced by the operator moving handle (5) to the left, which opens the feed gate (6) by turning spindle (7), which is in two parts and to which both feed gate and lever (5) are fastened. Attached to the other part of spindle (7) at the opposite end from the operating lever is a short lever (8), to the opposite end of which is fastened a link (9). The link (9) connects lever (8) with the trip lever (10) in such a way that when the feed gate is open, the link (9) takes up a position in which its centre line lies practically continuous with the centre line of the trip lever (10), in which position the linkage becomes locked and thus holds open the feed gate. As the bag fills with cubes, the beam sinks under their weight until at some predetermined weight, usually about 5 lb.

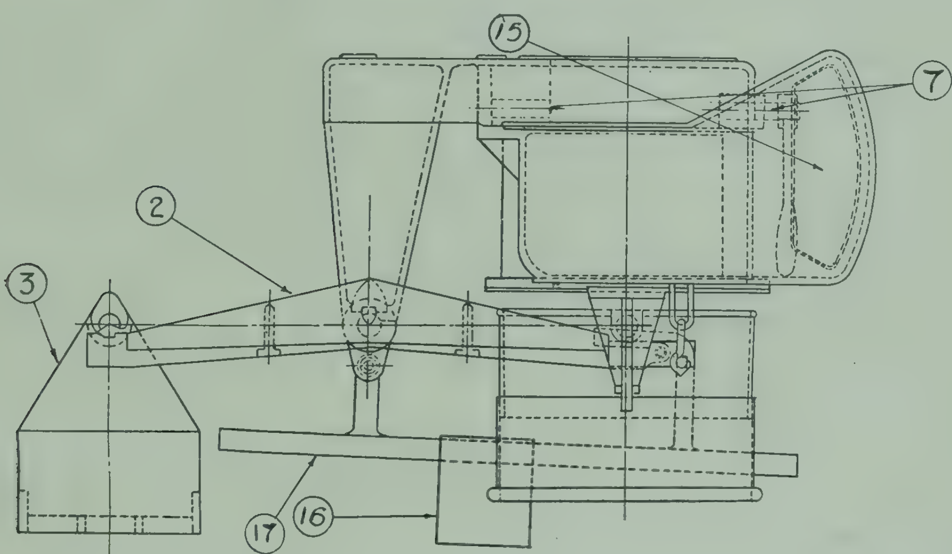


Fig. 136 View in Direction of arrow "A"

short of the required weight, the downward movement of the sack end of the beam causes the tripper arm (11) to contact the arm (12) of trip lever (10) and thus upsets the locked position of the linkage, consequently allowing the feed gate to shut under its own weight.

The bag now contains a quantity of cubes just short of the required weight and the extra cubes required to complete the weighment are fed into the bag by operating the swinging tray (13) by handle (14) until the pointer on dial (15) shows a correct reading. The bag is then dropped and the operation recommenced.

If it is found that the main gate is letting too many cubes into the bag before closing, this may be corrected by moving the compensating weight (16) along the compensating lever (17).

Should it be found that the feed gate is closing too soon, leaving an excessive weight of cubes to be shaken in by the hand-operated tray, then a contrary movement of the compensating weight can be made to correct this. A device is incorporated in the dial pointer chamber which allows the rate of movement of the pointer to be controlled. When possing or shaking down the contents of the bag whilst it is still fastened to the weigher, the bag should be pressed upwards to relieve the weight on the beam and the beam locked by operation of the locking lever provided for this purpose.

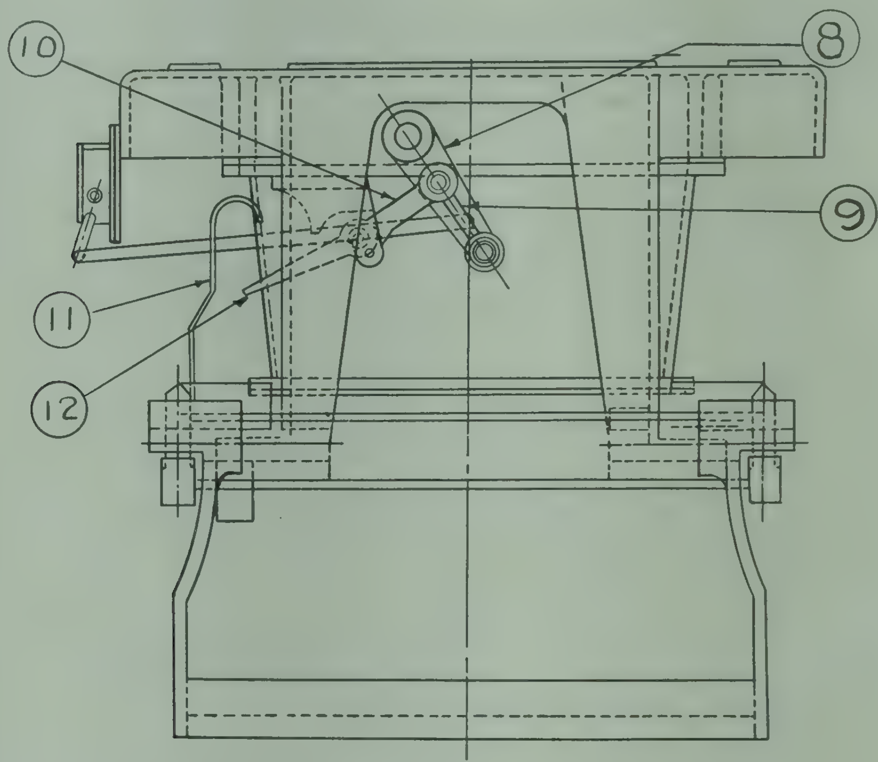


Fig. 136 Rear View

Failure to observe this precaution will result in a decided shortening of the life of the knife edges upon which the beam balances. If it should be found that the material flows too freely past the feed gate, the adjustable plate (18) should be moved in an anticlockwise direction to increase its interference with the flow. If the material is sluggish, the plate (18) may be removed altogether.

Compound meals and provender products may be packed and weighed as for cubes by a simple spout and portable platform weigher or by one of a range of automatic combined weigher packers. The valve controlling the flow of meal from the bag spout is commonly of the " butterfly " or " wing " type. In this type of valve, a circular valve plate fits inside the spout.

The plate is fastened to a spindle which runs through the spout and to which an operating lever is fastened. The spindle is also fitted with a weight so that when the operator takes his hand away, the valve tends to assume a closed position. This type of valve is free from many of the disadvantages of the slide type.

A number of differences arise both in procedure and machines from the machines and methods described for cubes. The first point of difference is demonstrated by the need for packing some products compactly in the bag, as for instance is the case with flaked cereals, and for this purpose some form of mechanical packer or posser is a real advantage.

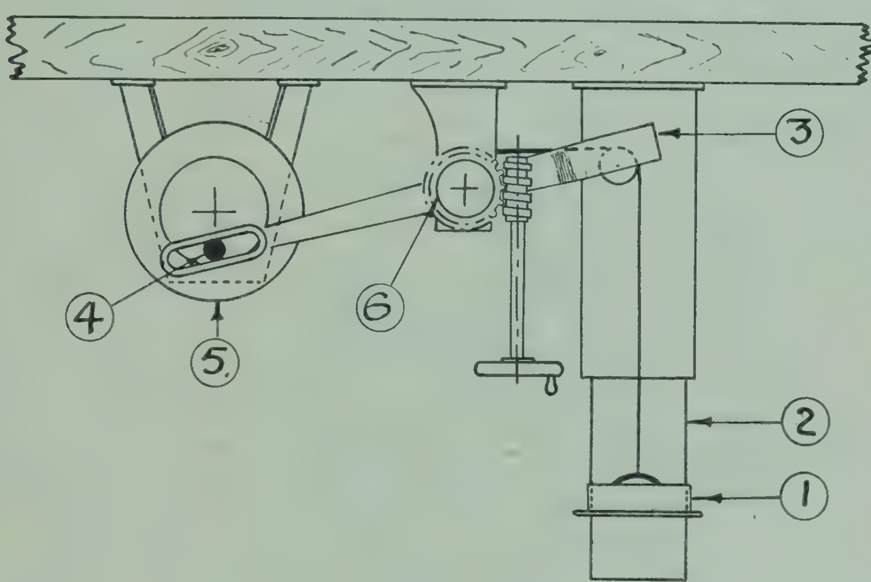


Fig. 137 Mechanical Posser

There are a number of types of mechanical possers, one of the earlier designs, which is still widely used, is illustrated in Fig. 2. The sacking-off mouthpiece (1) fits closely to, but is free to slide up and down the spout (2). The mouthpiece casting is supported by two chains fastened to one end of a pivoted beam (3), the other end of which is slotted to contain a crank pin (4) which is fitted to the disc (5). The disc is mounted on a shaft carrying a pair of fast and loose pulleys driven from some convenient source of power. It will be seen that as the disc revolves, the crank pin will alternately raise and lower the slotted end of the beam, which movement will be transmitted via the beam and chains to the spout mouthpiece and to the bag which may be fastened to it. The lift of the mouthpiece may be varied by altering the distance from the centre of the disc to the crank pin which is made adjustable for this purpose.

In the posser illustrated, allowance for a variety of sizes of bags is made by making the position of the mouthpiece adjust-

able. The adjustment is made possible by arranging for the chains supporting the mouthpiece to be taken over the end of the oscillating beam and fastened to a small hand operated winch drum (6). Other types of possers are those to be found adapted for use with automatic weighers such as that in which two upright timber posts are rigidly fixed in a position behind the bag being filled. Between the fixed posts is located a hinged plate capable of being swung forward by mechanical means pushing the bag forward with it. At the limit of its forward stroke, the plate returns rapidly to its original position and the

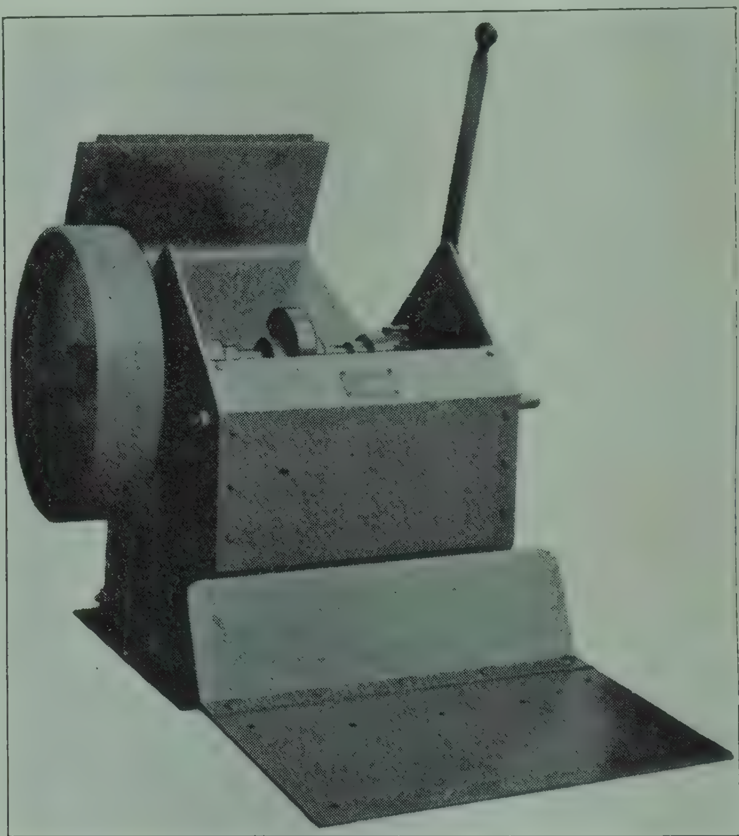


Fig. 138

bag, relieved of its support, falls back to strike smartly against the two fixed posts.

The "Reform" mechanical posser, made by Messrs. Henry Simon Ltd., is illustrated in Fig. 138, in which the plate, over which the bag being filled is suspended, is actuated by a cam and roller mechanism so that it rises, lifting the bag with it. When the plate reaches the top of its travel, it returns sharply to the bottom position, so that the jerk given to the bag settles down the material with which the bag is being filled. The lifting plate is counterbalanced so that it remains in the raised position until the weight of material in the bag depresses it, whereupon the possing action commences. The lever shown at

the far side of the posser is for stopping and starting the apparatus by sliding the roller arm out of the path of the lifting cam, thus avoiding the use of belt striking gear or clutches.

SACKS.

Jute sacks are almost invariably used to contain compound cubes and meals, although white calico sacks are occasionally used for special lines. From time to time, the suggestion is made that compound mill products could, with advantage, be packed in tough paper sacks, but it seems almost certain that the disadvantages would equal the advantages. For the use of paper sacks it is claimed that there is a reduction in the risk of disease being carried from one farm to another, because the bag is destroyed after being used once. Vermin find paper sacks

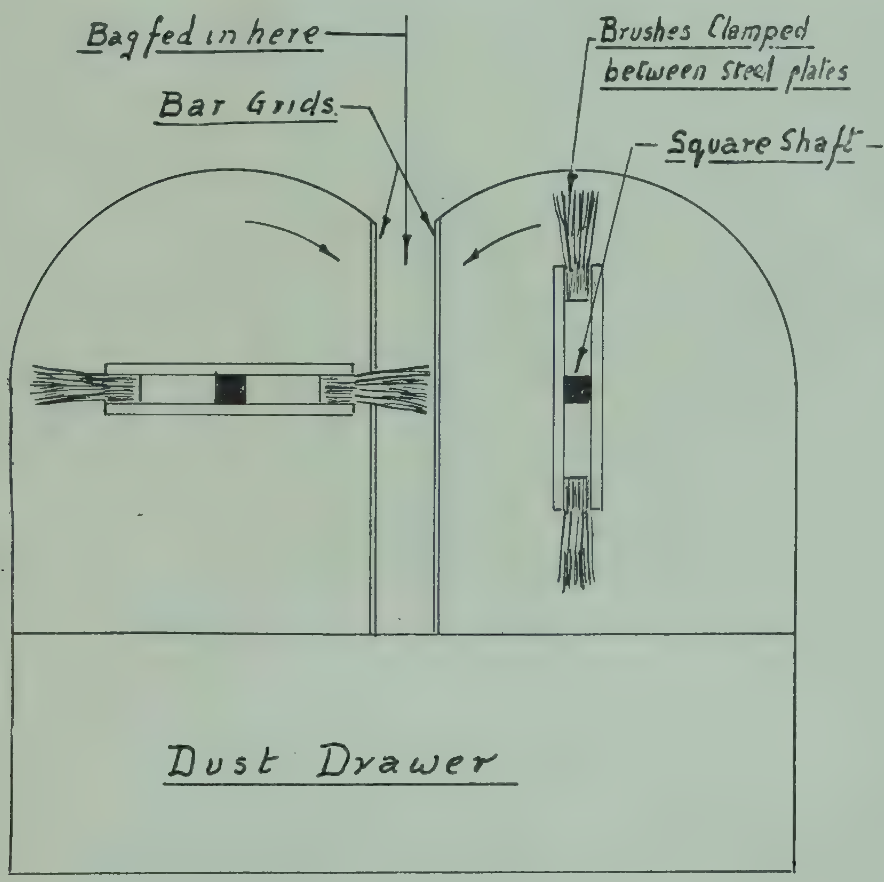


Fig. 139

a less attractive proposition than jute or calico, and paper is usually cheaper than the normal bag materials. Against the use of paper sacks, it may be considered that they are less resistant to injury in the case of careless handling or being subject to wet weather, that their more or less impervious nature does not allow the contents of the bag to breathe, thus products packed in them would have to be cooler and drier than when packed

into hessian sacks. Paper bags have no second-hand value. For a variety of reasons the use of paper bags has still to make a serious appeal to both farmers and millers.

The majority of manufactured products are packed in hessians, whilst the millers' raw materials may be received in a wide variety of bags including twills usually containing oil mill products and known as cake twills, large flour mill by-product bags measuring 56 in. x 28 in., sometimes called five bushel bags, a number of bags bearing names like Bombay's and Green Bombays containing imported products, rice meal bags, which are a peculiar coarse weave, and sugar bags which are usually a blue striped twill. In times of sack shortage, some of these bags may be used to contain finished compound products, particularly the cake twills, but in time of normal supply, all manufactured products are dispatched in new bags which are non-returnable, however the shortage of sack supply may oblige the miller to encourage farmers to return empty sacks with which the farmer's account is credited.

Cubes may be packed in 140 lb. bags measuring 40 in. x 28 in., or sometimes 45 in. x 25 in., or in 112 lb. bags measuring 43 in. x 24 in.

Molassed P.K. meal may be packed in extra large hessian measuring 54 in. x 30 in.

Calf meals are often bagged not only in cwts., but also in bags containing 56 lb. and 28 lb.

Most large millers have printed upon their sacks their trade mark and/or name along with a descriptive title of the contents of the bags, the weight contained therein and possibly a statement of the oil, protein and fibre contents of the feeding stuff. The printing of the sacks may be carried out by the sack supplier or the mill may have its own sack printing department for this purpose.

In view of the wide range of products which the compound miller manufactures, and the fact that he is likely to be asked for any of these products upon the shortest notice, a sack printing department is an asset because it makes unnecessary the storing of large quantities of printed sacks covering the complete range of his products and for some of which the demand may be very uncertain. Also, a correction or alteration in the information printed upon a sack is not such a serious matter if, say, only a few hours requirements of printed sacks are carried as stock. Sacks having special markings can be printed at very short notice, all of which increase the flexibility of the miller's capacity to deliver his goods.

SACK CLEANING.

The cleaning of sacks is undertaken by the miller for a number of reasons, not the least of which is that the cleaning may be considered as a continuation of the emptying operation in which that part of the sack's contents which remains trapped in the crevices and weave of the bag is removed. The removal of this apparently insignificant quantity of materials is more than able to pay for the cost of cleaning, apart from making

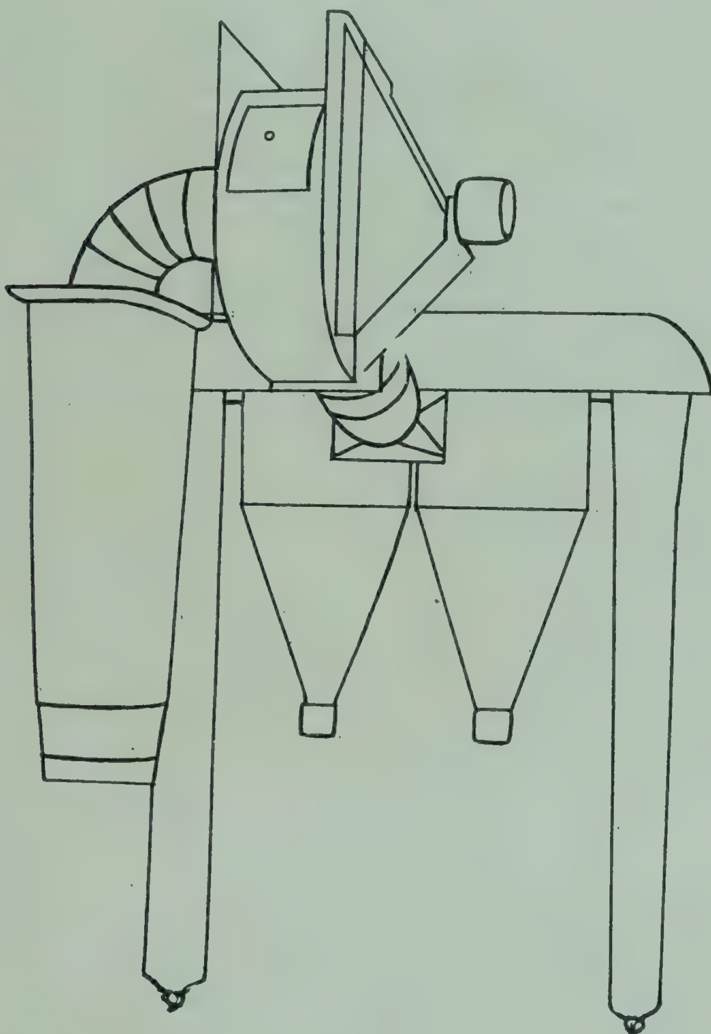


Fig. 140

sacks available for re-use if required, and cleaning also improves the conditions under which sacks may be repaired prior either to sale or re-use.

Probably one of the earliest mechanical sack cleaning devices is that shown in Fig. 139, in which the sack is fed between a pair of rotors carrying brushes which revolve in opposite directions.

The bag, after being lowered between the brushes, is then retracted. It will be noticed that the brushes actually pass between bars of a grid, the grid preventing the sack from being carried round by the brushes.

The most up-to-date method of cleaning sacks is by the use of pneumatic sack cleaners. The operation is simple and the action thorough and clean. The illustration (Fig. 140) shows the general construction of the pneumatic cleaner. The sack to be cleaned is held mouth uppermost over the suction tube and the air flow pulls the sack up into the tube at the same time turning it inside out. The sack is pulled down the tube by the operator and the action repeated to turn the bag right side out. The dust which has been removed from the bags during this operation is blown by the fan into the cyclone separators where most of the dust settles out and is deposited in the hoppers to the mouths of which are fitted sacks. The air escapes from the separators via the dust chamber and fabric tubes which filter from it any light dust which has been entrained. Should the operator lose his grip upon a sack being cleaned, the sack is prevented from reaching the fan by a bar grid stretched across the suction tube near the top, and upon the fan being stopped the sack will fall out of the tube.